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PROCEEDINGS

OF THE

THIRTEENTH ANNUAL CONVENTION

OF THE

American Railway Engineering Association

HELD AT THE

CONGRESS HOTEL, CHICAGO, ILLINOIS

March 19, 20 and 21, 1912

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CONSTITUTION

CONSTITUTION.

REVISED AT THE FIFTH, EIGHTH AND TWELFTH ANNUAL CONVENTIONS.

ARTICLE I.

NAME, OBJECT AND LOCATION.

Name.

1. The name of this Association is the AMERICAN RAILWAY ENGINEERING ASSOCIATION.

Object.

2. Its object is the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways.

Means to be Used.

3. The means to be used for this purpose shall be as follows:

(a) Meetings for the reading and discussion of reports and papers and for social intercourse.

(b) The investigation of matters pertaining to the objects of this Association through Standing and Special Committees.

(c) The publication of papers, reports and discussions.

(d) The maintenance of a library.

Responsibility.

4. Its action shall be recommendatory, and not binding upon its members.

Location of Office.

5. Its permanent office shall be located in Chicago, Ill., and the annual convention shall be held in that city.

ARTICLE II.

MEMBERSHIP.

Membership Classes.

1. The membership of this Association shall be divided into three classes, viz.: Members, Honorary Members and Associates.

Membership Qualifications.

(2) A Member shall be:

(a) Either a Civil Engineer, a Mechanical Engineer, an Electrical Engineer, or an official of a railway corporation, who has had not less than five (5) years' experience in the location, construction, maintenance or operation of railways, and who, at the time of application for membership, is engaged in railway service in a responsible position in charge of work connected with the Location, Construction, Operation or Maintenance of a Railway; provided, that all persons who were Active Members prior to March 20, 1907, shall remain Members except as modified by Article II, Clause 9.

(b) A Professor of Engineering in a college of recognized standing

Honorary Membership Qualifications.

3. An Honorary Member shall be a person of acknowledged eminence in railway engineering or management. The number of Honorary Members shall be limited to ten.

Associate Membership Qualifications.

4. An Associate shall be a person not eligible as a Member, but whose pursuits, scientific acquirements or practical experience qualify him to co-operate with Members in the advancement of professional knowledge, such as Consulting, Inspecting, Contracting, Government or other Engineers, Instructors of Engineering in Colleges of recognized standing, and Engineers of Industrial Corporations when their duties are purely technical.

Membership Rights.

5. (a) Members shall have all the rights and privileges of the Association.

(b) Honorary Members shall have all the rights of Members, except that of holding office, and shall be exempt from the payment of dues.

(c) Associates shall have all the rights of Members, except those of voting and holding office.

Age Requirement.

6. An applicant to be eligible for membership in any class shall not be less than twenty-five (25) years of age.

"Railway" Defined.

7. The word "railway" in this Constitution means one operated by steam or electricity as a common carrier, dependent upon transportation for its revenue. Engineers of street railway systems and of railways which are used primarily to transport the material or product of an industry or industries to and from a point on a railway which is a common carrier, or those which are merely adjuncts to such industries, are eligible only as Associates.

Changes in Classes.

8. A Member, elected after March 20, 1907, who shall leave the railway service, shall cease to be a Member, but may retain membership in the Association as an Associate, subject to the provisions of Article II, Clause 9; provided, however, if he re-enters the railway service, he shall be restored to the class of Members.

Supply Men.

9. Persons whose principal duties require them to be engaged in the sale or promotion of railway patents, appliances or supplies, shall not be eligible for, nor retain membership in any class in this Association, except that those who were Active Members prior to March 20, 1907, may retain membership as Associates; provided, however, that anyone having held membership in the Association and subsequently having become subject to the operation of this clause, shall, if he again becomes eligible, be permitted to re-enter the Association, without the payment of a second entrance fee.

Transfers.

10. The Board of Direction shall transfer members from one class to another, or remove a member from the membership list, under the provisions of this Article.

ARTICLE III.

ADMISSIONS AND EXPULSIONS.

Charter Membership.

1. The Charter Membership consists of all persons who were elected before March 15, 1900.

Application for Membership.

2. The Charter Membership having been completed, any person desirous of becoming a member shall make application upon the form prescribed by the Board of Direction, setting forth in a concise statement his name, age, residence, technical education and practical experience. He shall refer to at least three members to whom he is personally known, each of whom shall be requested by the Secretary to certify to a personal knowledge of the candidate and his fitness for membership.

Election to Membership.

3. Upon receipt of an application properly endorsed, the Board of Direction, through its Secretary, or a Membership Committee selected from its own members, shall make such investigation of the candidate's fitness as may be deemed necessary. The Secretary will furnish copies of the information obtained and of the application to each member of the Board of Direction. At any time, not less than thirty days after the filing of the application, the admission of the applicant shall be canvassed by letter-ballot among the members of the Board, and affirmative votes by two-thirds of its members shall elect the candidate; provided, however, that should an applicant for membership be personally unknown to three members of the Association, due to residence in a foreign country, or in such a portion of the United States as precludes him from a sufficient acquaintance with its members, he may refer to well-known men engaged in railway or allied professional work, upon the form above described, and such application shall be considered by the Board of Direction in the manner above set forth, and the applicant may be elected to membership by a unanimous vote of the Board.

Subscription to Constitution.

4. All persons, after due notice from the Secretary of their election, shall subscribe to the Constitution on the form prescribed by the Board of Direction. If this provision be not complied with within six months of said notice, the election shall be considered null and void.

Reinstatement.

5. Any person having been a member of this Association, and having, while in good standing, resigned such membership, may be reinstated without the payment of a second entrance fee; provided his application for reinstatement is signed by five members certifying to his fitness for same, and such application is passed by a two-thirds majority of the Board of Direction.

Honorary Membership.

6. Proposals for Honorary Membership shall be submitted by ten or more Members. Each Member of the Board of Direction shall be furnished with a copy of the proposal, and if, after thirty days, the nominee shall receive the unanimous vote of said Board, he shall be declared an Honorary Member.

Expulsions.

7. When charges are preferred against a Member in writing by ten or more Members, the Member complained of shall be served with a copy of such charges, and he shall be called upon to show cause to the Board of Direction why he should not be expelled from the Association. Not less than thirty days thereafter a vote shall be taken on his expulsion, and he shall be expelled upon a two-thirds vote of the Board of Direction.

Resignations.

8. The Board of Direction shall accept the resignation, tendered in writing, of any Member whose dues are fully paid up.

ARTICLE IV.

DUES.

Entrance Fee.

1. An entrance fee of $10.00 shall be payable to the Association through its Secretary with each application for membership; and this sum shall be returned to the applicant if not elected.

Annual Dues.

2. The annual dues are $10.00, payable during the first three months of the calendar year.

Arrears.

3. Any person whose dues are not paid before April 1st of the current year shall be notified of same by the Secretary. Should the dues not be paid prior to July 1st, the delinquent Member shall lose his right to vote. Should the dues remain unpaid October 1st, he shall be notified on the form prescribed by the Board of Direction, and he shall no longer receive the publications of the Association. If the dues are not paid by December 31st, he shall forfeit his membership without further action or notice, except as provided for in Clause 4 of this Article.

Remission of Dues.

4. The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member, who, from ill-health, advanced age or other good reasons, is unable to pay them.

ARTICLE V.

OFFICERS.

Officers.

1. The officers of the Association shall be Members and shall consist of:

A President,
A First Vice-President,
A Second Vice-President,
A Treasurer,
A Secretary,
Nine Directors,

who, together with the five latest living Past-Presidents who are Members, shall constitute the Board of Direction in which the government of the Association shall be vested, and who shall act as Trustees, and have the custody of all property belonging to the Association.

Vice-Presidents' Priority.

2. The offices of First and Second Vice-Presidents shall be determined by the priority of their respective dates of election.

Terms of Office.

3. The terms of office of the several officers shall be as follows:

President, one year.
Vice-Presidents, two years.
Treasurer, one year.
Secretary, one year.
Directors, three years.

Officers Elected Annually.

4. (a) There shall be elected at each Annual Convention:

A President,
One Vice-President,
A Treasurer,
A Secretary,
Three Directors.

(b) The candidates for President and for Vice-President shall be selected from the members of the Board of Direction.

Conditions of Re-election of Officers.

5. The office of President shall not be held twice by the same person. A person who shall have held the office of Vice-President or Director shall not be eligible for re-election to the same office until at least one full term shall have elapsed after the expiration of his previous term of office.

Term of Officers.

6. The term of each officer shall begin with his election and continue until his successor is elected.

Vacancies in Offices.

7. (a) A vacancy in the office of President shall be filled by the First Vice-President.

(b) A vacancy in the office of either of the Vice-Presidents shall be filled by the Board of Direction by election from the Directors. A Vice-Presidency shall not be considered vacant when one of the Vice-Presidents is filling a vacancy in the Presidency.

(c) Any other vacancies for the unexpired term in the membership of the Board of Direction shall be filled by the Board.

(d) An incumbent in any office for an unexpired term shall be eligible for re-election to the office he is holding; provided, however, that anyone appointed to fill a vacancy as Director within six months after the term commences shall be considered as coming within the provision of Article V, Clause 5.

Vacation of Office.

8. When an officer ceases to be a Member of the Association, as provided in Article II, his office shall be vacated, and be filled as provided in Article V, Clause 7.

Disability or Neglect

9. In case of the disability or neglect in the performance of his duty, of an officer, the Board of Direction, by a two-thirds majority vote of the entire Board, shall have power to declare the office vacant, and fill it as provided in Article V, Clause 7.

ARTICLE VI.

NOMINATION AND ELECTION OF OFFICERS.

Nominating Committee.

1. (a) There shall be a Nominating Committee composed of the five latest living Past-Presidents of the Association, who are Members, and five Members not officers.

(b) The five Members shall be elected annually when the officers of the Association are elected.

Number of Candidates

2. It shall be the duty of this committee to nominate candidates to fill the offices named in Article V, and vacancies in the Nominating Committee caused by expiration of term of service, for the ensuing year, as follows:

Office to be Filled.	Number of Candidates to be named by Nominating Committee.	Number of Candidates to be elected at Annual Election of Officers.
President	1	1
Vice-President	1	1
Treasurer	1	1
Secretary	1	1
Directors	9	3
Nominating Committee	10	5

Chairman. 3. The Senior Past-President shall act as permanent chairman of the committee, and will issue the call for meetings. In his absence from meetings, the Past-President next in age of service shall act as Chairman pro tem. at the meeting.

Meeting of Committee. 4. Prior to December 1st, each year, the Chairman shall call a meeting of the committee at a convenient place and, at this meeting, nominees for office shall be agreed upon.

Announcement of Names of Nominees. 5. The names of the nominees shall be announced by the permanent Chairman to the President and Secretary not later than December 15th of the same year, and the Secretary shall report them to the Members of the Association on a printed slip not later than January 1st following.

Additional Nominations by Members. 6. At any time between January 1st and February 1st, any ten or more Members may send to the Secretary additional nominations for the ensuing year signed by such Members.

Vacancies in List of Nominees. 7. If any person so nominated shall be found by the Board of Direction to be ineligible for the office for which he is nominated, or should a nominee decline such nomination, his name shall be removed and the Board may substitute another one therefor; and may also fill any vacancies that may occur in this list of nominees up to the time the ballots are sent out.

Ballots Issued. 8. Not less than thirty days prior to each Annual Convention, the Secretary shall issue ballots to each voting member of record in good standing, with a list of the several candidates to be voted upon, with the names arranged in alphabetical order when there is more than one name for any office.

Substitution of Names. 9. Members may erase names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names voted for each office on the ballot must not exceed the number to be elected at that time to such office.

Ballots. 10. (a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed or deposited with the Secretary at any time previous to the closure of the polls.

(b) A voter may withdraw his ballot, and may substitute another, at any time before the polls close.

Invalid Ballots. 11. Ballots not endorsed or from persons not qualified to vote shall not be opened; and any others not complying with the above provisions shall not be counted.

Closure of Polls. 12. The polls shall be closed at twelve o'clock noon on the second day of the Annual Convention, and the ballots shall be counted by three tellers appointed by the Presiding Officer. The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

Requirements for Election. 13. The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

Tie Vote. 14. In case of a tie between two or more candidates for the same office, the members present at the Annual Convention shall elect the officer by ballot from the candidates so tied.

15. The Presiding Officer shall announce at the convention the names of the officers elected in accordance with this Article. Announcement.

16. Except as to the Past-Presidents, the first Nominating Committee and the three additional Directors provided for shall be appointed by the Board of Direction, one of the Directors for one year, one for two years, and one for three years. First Nominating Committee.

ARTICLE VII.

MANAGEMENT.

1. (a) The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association and of the Board of Direction, and shall be ex-officio member of all Committees, except the Nominating Committee. Duties of President.

(b) The Vice-Presidents, in order of seniority, shall preside at meetings in the absence of the President and discharge his duties in case of a vacancy in his office.

2. The Treasurer shall receive all moneys and deposit same in the name of the Association, and shall receipt to the Secretary therefor. He shall invest all funds not needed for current disbursements as shall be ordered by the Board of Direction. He shall pay all bills, when properly certified and audited by the Finance Committee, and make such reports as may be called for by the Board of Direction. Duties of Treasurer.

3. The Secretary shall be, under the direction of the President and Board of Direction, the Executive Officer of the Association. He shall attend the meetings of the Association and of the Board of Direction, prepare the business therefor, and duly record the proceedings thereof. He shall see that the moneys due the Association are collected and without loss transferred to the custody of the Treasurer. He shall personally certify to the accuracy of all bills or vouchers on which money is to be paid. He is to conduct the correspondence of the Association and keep proper record thereof, and perform such other duties as the Board of Direction may prescribe. Duties of Secretary.

4. The accounts of the Treasurer and Secretary shall be audited annually by a public accountant, under the direction of the Finance Committee of the Board. Auditing of Accounts.

5. The Board of Direction shall manage the affairs of the Association, and shall have full power to control and regulate all matters not otherwise provided in the Constitution. Duties of Board.

6. The Board of Direction shall meet within thirty days after each Annual Convention, and at such other times as the President may direct. Special meetings shall be called on request, in writing, of five members of the Board. Board Meetings.

7. Seven members of the Board shall constitute a quorum. Board Quorum.

8. At the first meeting of the Board after the Annual Convention, the following committees from its members shall be appointed by the President, and shall report to and perform their duties under the supervision of the Board of Direction: Board Committees.

a. Finance Committee of three members.
b. Publication Committee of three members.
c. Library Committee of three members.
d. Outline of Work of Standing Committees of five members.

Duties of Finance Committee.

9. The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of moneys and as to other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money other than the amounts necessary to meet ordinary current expenses of the Association, except by previous action and authority of the Board of Direction.

Duties of Publication Committee.

10. The Publication Committee shall have general supervision of the publications of the Association.

Duties of Library Committee.

11. The Library Committee shall have general supervision of the Library, the property therein, and the quarters occupied by the Secretary; shall make recommendations to the Board with reference thereto, and shall direct the expenditure for books and other articles of permanent value, from such sums as may be appropriated for these purposes.

Duties of Committee or Outline of Work of Standing Committees.

12. The Committee on Outline of Work of Standing Committees shall present a list of subjects for committee work during the ensuing year at the first meeting of the Board of Direction after the Annual Convention.

Standing Committees.

13. The Board of Direction may appoint such Standing Committees as it may deem best, to investigate, consider and report upon questions pertaining to railway location, construction or maintenance.

Special Committees.

14. Special Committees to examine into and report upon any subject connected with the objects of this Association may be appointed from time to time by the Board of Direction.

Discussion by Non-Members.

15. The Board of Direction may invite discussions of reports from persons not members of the Association.

Sanction of Acts of Board.

16. An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next Annual Convention of the Association shall be deemed to be the act of the Association, and shall not afterwards be impeached by any Member.

ARTICLE VIII.

MEETINGS.

Annual Convention.

1. The Annual Convention shall begin upon the third Tuesday in March of each year, and shall be held at such place in the City of Chicago as the Board of Direction may select.

Special Meetings.

2. Special meetings of the Association may be called by the Board of Direction, and special meetings shall be so called by the Board upon request of thirty Members, which request shall state the purpose of such meeting. The call for such meeting shall be issued not less than ten days in advance, and shall state the purpose and place thereof, and no other business shall be taken up at such meeting.

3. The Secretary shall notify all members of the time and place of the Annual Convention of the Association at least thirty days in advance thereof. Notification of Annual Convention.

4. Twenty-five Members shall constitute a quorum at all meetings of the Association. Association Quorum.

5. (a) The order of business at annual conventions of the Association shall be as follows: Order of Business.

Reading of minutes of last meeting.
Address of the President.
Reports of the Secretary and Treasurer.
Reports of Standing Committees.
Reports of Special Committees.
Unfinished business.
New business.
Election of officers.
Adjournment.

(b) This order of business, however, may be changed by a majority vote of members present.

6. The proceedings shall be governed by "Robert's Rules of Order," except as otherwise herein provided. **Rules of Order.**

7. Discussion shall be limited to members and to those invited by the presiding officer to speak. **Discussion.**

ARTICLE IX.

AMENDMENTS.

1. Proposed amendments to this Constitution shall be made in writing and signed by not less than ten Members, and shall be acted upon in the following manner: **Amendments**

The amendments shall be presented to the Secretary, who shall send a copy of same to each member of the Board of Direction as soon as received. If at the next meeting of the Board of Direction a majority of the entire Board are in favor of considering the proposed amendments, the matter shall then be submitted to the Association for letter-ballot, and the result announced by the Secretary at the next Annual Convention. In case two-thirds of the votes received are affirmative, the amendments shall be declared adopted and become immediately effective.

GENERAL INFORMATION.

(Subject to change from time to time by Board of Direction.)

GENERAL RULES FOR THE PREPARATION, PUBLICATION AND CONSIDERATION OF COMMITTEE REPORTS.

(A) APPOINTMENT OF COMMITTEES AND OUTLINE OF WORK.

Standing Committees.

1. The following are standing committees:

I. Roadway.
II. Ballast.
III. Ties.
IV. Rail.
V. Track.
VI. Buildings.
VII. Wooden Bridges and Trestles.
VIII. Masonry.
IX. Signs, Fences and Crossings.
X. Signals and Interlocking.
XI. Records and Accounts
XII. Rules and Organization.
XIII. Water Service.
XIV. Yards and Terminals.
XV. Iron and Steel Structures.
XVI. Economics of Railway Location.
XVII. Wood Preservation.
XVIII. Electricity.
XIX. Conservation of Natural Resources.

Special Committees.

2. Special Committees will be appointed from time to time, as may be deemed expedient, in the manner prescribed by Article VII, Clause 14, of the Constitution.

Personnel of Committees.

3. The personnel of all Committees will continue from year to year, except when changes are announced by the Board of Direction.

Outline of Work.

4. As soon as practicable after each annual convention the Board of Direction will assign to each Committee the important questions which, in its judgment, should preferably be considered during the current year. Committees are privileged to present the results of any special study or investigation they may be engaged upon or that may be considered of sufficient importance to warrant presentation.

(B) PREPARATION OF COMMITTEE REPORTS.

General.

5. The collection and compilation of data and subsequent analysis in the form of arguments and criticism is a necessary and valuable preliminary element of committee work.

Collection of Data.

6. Committees are privileged to obtain data or information in any proper way. If desired, the Secretary will issue circulars of inquiry, which should be brief and concise. The questions asked should be specific and pertinent, and not of such general or involved character as to preclude the possibility of obtaining satisfactory and prompt responses. They should specify to whom answers are to be sent, and should be in such form that copies can be retained by persons replying either by typewriter or blue-print.

Plan of Reports

7. Committee reports should be prepared as far as practicable to conform to the following general plan:

(a) It is extremely important that every Committee should examine its own subject-matter in the "Manual" prior to each annual convention, and revise and supplement it, if deemed desirable, giving the necessary notice of any recommended changes in accordance with Clause 6 (a) of the General Rules for the Publication of the "Manual." If no changes are recommended, statement should be made accordingly.

(b) When deemed necessary, the previous report should be reviewed.

(c) Subjects presented in previous reports on which no action was taken should be resubmitted, stating concisely the action desired. It may not be necessary to repeat the original text in the report, reference to former publication being sufficient, unless changes in the previously published version are extensive. Minor changes can be explained in the text of the report.

Definitions.

(d) Technical terms used in the report, the meaning of which is not clearly established, should be defined, but defined only from the standpoint of railway engineering.

History.

(e) If necessary, a brief history of the subject-matter under discussion, with an outline of its origin and development, should be given.

Analysis.

(f) An analysis of the most important elements of the subject-matter should be given.

Argument.

(g) The advantages and disadvantages of the present and recommended practices should be set forth.

Illustrations

(h) Illustrations accompanying reports should be prepared so that they can be reproduced on one page. The use of folders should be avoided as much as possible, on account of the increased expense and inconvenience in referring to them. Plans showing current practice, or necessary for illustration, are admissible, but those showing proposed definite design or practice should be excluded. Recommendatoins should be confined to governing principles.

Illustrations should be made on tracing cloth with heavy black lines and figures, so as to stand a two-thirds reduction; for example: To come within a type page (4 inches by 7 inches), the illustration should be made three times the above size.

To insure uniformity, the one-stroke, inclined Gothic lettering is recommended.

Photographs should be clear and distinct silver prints.

Conclusions.

Plans showing current practice, or necessary for illustration, are admissible, but those showing proposed definite design or practice should be excluded. Recommendations should be confined to governing principles.

(i) The conclusions of the Committee which are recommended for publication in the Manual should be stated in concise language, logical sequence, and grouped together, setting forth the principles, specifications, definitions, forms, tables and formulæ included in the recommendation. Portions of the text of the report which are essential to a clear interpretation and understanding of the conclusions, should be included as an integral part thereof.

(c) PUBLICATION OF COMMITTEE REPORTS.

Reports Required.

8. (a) Reports will be required from each of the Standing and Special Committees each year.

(b) Although several subjects may be assigned to each Committee by the Board of Direction, a full report on only one subject is expected at each annual convention, but the preliminary work on some of the remaining subjects should be in progress, and, when deemed advisable, partial reports of progress should also be presented. This method allows time for their proper preparation and consideration.

Date of Filing Reports.

9. Committee reports to come before the succeeding convention for discussion should be filed with the Secretary not later than November, 30 of each year.

10. Committees engaged upon subjects involving an extended investigation and study are privileged to present progress reports, giving a brief statement of the work accomplished, and, if deemed expedient, a forecast of the final report to be presented.

Publication of Reports.

11. Committee reports will be published in the Bulletin in such sequence as the Board of Direction may determine, for consideration at the succeeding convention. Reports will be published in the form presented by the respective Committees. Alterations ordered by the convention will be printed as an appendix to the report.

Written Discussions.

12. Committees should endeavor to secure written discussions of published reports. Written discussions will be transmitted to the respective Committees, and if deemed desirable by the Committee, the discussions will be published prior to the convention and be considered in connection with the report.

Verbal Discussions.

13. Each speaker's remarks will be submitted to him in writing before publication in the Proceedings, for the correction of diction and errors of reporting, but not for the elimination of remarks.

(d) CONSIDERATION OF COMMITTEE REPORTS.

Sequence.

14. The sequence in which Committee reports will be considered by the convention will be determined by the Board of Direction.

15. The method of consideration of Committee reports will be one of the following: Method.

(a) Reading by title.

(b) Reading, discussing and acting upon each conclusion separately.

(c) By majority vote, discussion will be had on each item. Clauses not objected to when read will be considered as voted upon and adopted.

16. Action by the convention on Committee reports will be one of the following, after discussion is closed: Final Action.

(a) Receiving as information.

(b) Receiving as a progress report.

(c) Adoption of a part complete in itself and referring remainder back to Committee.

(d) Adoption as a whole.

(e) Recommittal with or without instructions.

(f) Adoption as a whole.

(g) Recommendation to publish in the Manual.

NOTE.—An amendment which affects underlying principles, if adopted, shall of itself constitute a recommittal of such part of the report as the Committee considers affected.

The Chair will decline to entertain amendments which in his opinion lie entirely within the duties of the Editor.

GENERAL RULES FOR THE PUBLICATION OF THE "MANUAL."

Title.

1. The title of the volume will be "Manual of the American Railway Engineering Association."

2. The Board of Direction shall edit the Manual and shall have authortiy to withhold from publication any matter which it shall consider as not desirable to publish, or as not being in proper shape, or as not having received proper study and consideration.

Adoption of Reports Not Binding.

3. Matters adopted by the Association and subsequently published in the Manual shall be considered in the direction of good practice, but shall not be binding on the members.

Contents.

4. The Manual will only include conclusions relating to definitions, specifications and principles of practice as have been made the subject of a special study by a Standing or Special Committee and embodied in a committee report, published not less than thirty days prior to the annual convention, and submitted by the Committee to the annual convention, and which, after due consideration and discussion, shall have been voted on and formally adopted by the Association. Subjects which, in the opinion of the Board of Direction, should be reviewed by the American Railway Association, may be referred to that Association before being published in the Manual.

5. All conclusions included in the Manual must be in concise and proper shape for publication, as the Manual will consist only of a summary record of the definitions, specifications and principles of practice adopted by the Association, with a brief reference to the published Proceedings of the Association for the context of the Committee report and subsequent discussion and the final action of the Association.

Revision.

6. Any matter published in the Manual may be amended or withdrawn by vote at any subsequent annual convention, provided such changes are proposed in time for publication not less than thirty days prior to the annual convention, and in the following manner: (a) Upon recommendation of the Committee in charge of the subject; (b) upon recommendation of the Board of Direction; (c) upon request of five members, made to the Board of Direction.

7. The Manual will be revised either by publishing a new edition or a supplemental pamphlet as promptly as possible after each annual convention.

BUSINESS SESSION

PROCEEDINGS.

The object of this Association is the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways. Its action is not binding upon its members.

TUESDAY, MARCH 19, 1912.

MORNING SESSION.

The Convention was called to order by Mr. W. C. Cushing, Chief Engineer Maintenance of Way, Pennsylvania Lines West of Pittsburgh, at 9:20 o'clock.

The President:—Gentlemen, please come to order.

The Thirteenth Annual Convention of our Association, now known for its first year under its new name, American Railway Engineering Association, ought to be an auspicious one, for was not "13" the number of the original States of our glorious Republic and "13" the number of letters in the motto of our State coat of arms, "E Pluribus Unum," while, in one claw, the eagle holds thirteen sharp-pointed arrows, and in the other an olive branch with thirteen leaves? Moreover, the words "City of Chicago," which lends its hospitality for our meeting, contain thirteen letters.

The Committee on Arrangements has been untiring in its zeal, and we are certain that our program has been well-prepared, and that we will have an enjoyable time.

The Railway Age-Gazette and the Railway and Engineering Review will prepare Daily Editions, thus helping to keep up our interest and inform us of the current events during the Convention. They are entitled to the gratitude and thanks of the members.

The privileges of the floor are extended to railway officials, engineers, and others not members of the Association, and they are cordially invited to participate in the discussions.

For the benefit of your fellow-members and the reporters, each speaker is requested, upon arising for recognition by the Chair, to state his name and the Company or College with which he is associated.

The first business to be attended to is the reading of the Minutes of the last Convention, but, as they have already been in print for some time, the reading will be dispensed with and the approval of the members considered as given, unless there is some objection.

There being no objection, the Minutes stand approved as printed.

Next in order is the report of the President.

PRESIDENT'S ADDRESS.

ASSOCIATION AFFAIRS.

To the Members of the American Railway Engineering Association:

At the last Annual Convention we numbered 967 Members, Honorary Members and Associates. During the year we have passed the 1,000 mark, although, naturally, our rate of growth has not been quite so rapid as in former years. As the date of our fiscal year has been changed from March to December 31st, it is difficult to make exact comparisons. The largest number of accretions in any one year was 124, in 1901, while in 1904 we had 104, and in 1911, 98 new members. From last March to December 31, 1911, only part of a year, 37 new members have joined.

During the first few years of the existence of the Association a comfortable cash surplus was accumulated, but in the last three years the amount of printed matter issued has grown to such an extent that our expenditures have been in excess of our receipts, and the surplus has been drawn upon. The following table gives approximately the number of printed pages issued in each year since the beginning:

	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	Totals
Constitution	54	....	....	....	....	....	....	....	....	....	....	....	....	54
Bulletins	....	172	513	430	1124	794	1028	1074	848	1302	2234	1990	1470	12979
Proceedings	....	244	825	598	602	1000	980	942	768	970	1778	1412	1982	12101
Manual	....	....	....	....	....	....	210	....	316	....	....	....	522	1048
Program	....	....	....	44	36	36	44	48	48	80	78	62	82	558
Miscellaneous	....	....	....	....	24	8	....	....	....	26	34	34	32	158
Totals	54	416	1338	1072	1786	1838	2262	2064	1980	2378	4124	3498	4330	27140

You will observe from this that during the last four years 14,330 pages, or more than half the total, have been printed, exceeding the number issued in the preceding nine years.

It was clear to your Board, therefore, that either the printing bill must be reduced, or the revenue increased, or both.

So far as increasing the revenues are concerned, your Board has been unwilling as yet to recommend an increase in annual membership dues, but is arranging for the present to obtain additional revenue by employing an advertising agent to secure advertisements for the Bulletins and Program. It is estimated that this arrangement will net about $4,000 annually. The advertisements, and methods of obtaining them, will be closely supervised, but, nevertheless, the members of the Board are opposed to the principle, and would not resort to it except in a case of emergency. It is hoped that the plan can be abolished at a future date, as in the case of the American Society of Civil Engineers.

With reference to reducing the expenditures, the Board has given a great deal of study to the question during the past year, and has made

some changes through the careful and energetic investigation of the Publication Committee and the Secretary.

First in importance is the Secretary's plan to avoid a reprinting of the reports for the Proceedings, after the Convention, by having a sufficient number of pages for the Proceedings printed at the same time as the Bulletins. The only disadvantage is that the discussions will be collected together at the end of the volume, instead of appearing at the end of the reports to which they refer, as in the past. This objection, however, was not considered of sufficient importance in comparison with the saving in printing, which is estimated to be about $1,000.

In addition to the above, but 10 Bulletins a year instead of 12 will be issued, the May and June numbers being omitted. This is done because it is usually difficult to obtain articles for them, and the Secretary is very busy during those months in preparing for the publication of the Proceedings. It is hoped that it will result in their earlier appearance. Moreover, a reduction in the number of Bulletins to be printed will be made, so that it will be necessary for members to bring their copies with them to the Convention. Some extra ones will be provided for those who prefer to purchase them at cost.

Further economy is expected in postal rates by obtaining the second-class mail privilege, application for which has been made to the Postmaster-General. All the prescribed details have been complied with, among which is the altered appearance of the cover of the Bulletins. In this connection it was necessary to establish regular subscription rates for our Bulletins, and we are also now advertising in them the established prices for all of our publications. The estimated reduction of expense for postage by this arrangement is about $500. It is of interest to know that we could not come under the regulations for this privilege till our Association numbered 1,000 persons.

The question of the use of a thinner and lighter weight paper for our publications is now before the Board, and its adoption will probably result in some economy of postage expense. The transactions of the American Society of Civil Engineers are hereafter to be issued in one volume printed on India paper, but its use would not be economical for this Association, because a special paper is required for the illustrations.

For a good while the Board of Direction realized that the number of subjects reported on by committees was apt to be too many for thorough discussion on the floor, considering the large number of standing committees, and introduced Rule 8-b for the preparation of committee reports, which limited the number to two for action by the Convention. A large number of subjects has always been assigned each year, so that the committees could be collecting subject matter for other reports to be presented a year or more hence. When the increase in expenses became alarming the Board found it necessary to have the President issue a special circular to committee chairmen, calling attention to the necessity for enforcing the rule strictly this year. The several committees have re-

sponded heartily to the request, and the results of their conscientious and painstaking work is apparent in the valuable reports presented.

The ideal method of increasing our revenues (without resorting either to the augmentation of the annual dues or to advertising) would be to secure a larger membership, approximately double the present number, as the expense involved in issuing the Bulletins and Proceedings is not much more for a membership of 2,000 than for one of 1,000, while the revenue would be doubled. While we are pleased with the present number of members, yet it is evident that many who are eligible and who would be most desirable confrères have not yet identified themselves with the Association.

In view of the unauthorized use of extracts from our Proceedings for advertising purposes by commercial agencies, your Board arranged for copyrighting all of our publications in the United States. It was not expedient to do so in Canada.

At the last Convention important changes in our Constitution were adopted, among which were the shortening of the name, the establishment of a Nominating Committee, in order to place a larger share of the management in the hands of the members, and the addition of three members to the Board of Direction. During the past year it has been found desirable to make some changes in the "General Rules for the Preparation, Publication and Consideration of Committee Reports," and the "General Rules for the Publication of the Manual," in order to make the work of the Association more expeditious and the papers and reports more valuable.

An invitation to send five delegates to the Third National Conservation Congress at Kansas City on September 25, 26 and 27, 1911, was extended to the Association, and Messrs. W. S. Kinnear, John V. Hanna, John R. Leighty, H. S. Moore and J. A. L. Waddell were named.

An invitation was issued to your Association through the subdepartment Secretaries of the Department of Commerce and Labor to participate with them, the Government engineers, and other engineering societies, in a conference for the purpose of unifying specifications for Portland Cement, and the invitation was accepted, the matter being put in the hands of Committee VIII—Masonry. We were advised by the Special Committee of the Departmental Conference that, on January 8, 1912, all parties had agreed to the preliminary specifications, except there was a difference of opinion as to whether the Vicat or Gilmore needles should be used for determining the time of setting. On January 17, the Committee of the American Society of Civil Engineers presented its final report, recommending the continued use of the Vicat needle for determining consistency and time of setting, which was accepted.

The Assistant Purchasing Agent of the Isthmian Canal Commission has written our Secretary for our rules covering creosote treatment of lumber and piling.

An invitation was also sent to this Association to send a representative to the convention of the International Association for Testing Materials to be held in September, 1912, and we will accept it.

The Association has received from Mr. Willard A. Smith, President of the Railway and Engineering Review, a valuable contribution of photographic views of the St. Gothard Railway in Switzerland, and another valuable contribution of a bound volume entitled "Railroad Transportation at the St. Louis World's Fair" from Mr. W. M. Camp, Editor of the same journal, both of which are in the Library.

Prof. W. F. M. Goss, Dean and Director of the University of Illinois, has tendered the use of data collected by the University, and the assistance of its staff, in the work of Committee XVI—Economics of Railway Location.

In 1910 the amount of money contributed by the American Railway Association for experiments and other work in connection with the study of the rail problem was $6,213.57, while the amount authorized by that Association for 1911 is $10,000. The results of the study are published in the Bulletins as fast as completed. In this connection you are informed that the following letter has been received by your President from Judge Wm. J. Wood, Chairman, Railroad Commission of Indiana:

"The Railroad Commission of Indiana has about decided to commence a formal inquiry into the condition of steel now being put into the railroad tracks of this State, involving, of course, a comparison of the steel now being constructed and that formerly used on the railroads of this State.

"I understand that your Association has had this matter up more than once, and I wish to have a conference with you about it in order, among other things, to have a suggestion from you, as to some person who could address a conference of Railroad Managers and Engineers, and other persons interested, held at Indianapolis under the direction of this Commission. Will you be in Chicago this week? I will thank you to advise me in reference to this subject, and whether or not I could meet you if I shall come there for that purpose.

"Yours very truly,

(Signed) "W. J. Wood, Chairman."

Your President called upon Judge Wood, and explained to him the work which Committee IV—Rail, has been doing.

At the meeting subsequently held on February 20, 1912, papers concerning the question of improvement of rail design and specifications were read by Messrs. P. H. Dudley (by representative), Thos. H. Johnson and W. C. Cushing, and, in addition, addresses were made by Messrs. F. A. Delano, E. J. Buffington, R. Montfort and Dr. Benjamin.

Your attention is called to the kindly expression of appreciation of our work in the editorial of the Railway and Engineering Review of October 28, 1911, page 940, and the statement on "Railway and Engineering Literature," page 944. These words should be a stimulus to further effort.

In the "Regulations adopted on December 28, 1911, by the Superintendents of Buildings of all Five Boroughs of the City of New York," relative to reinforced concrete, clause No. 9, says that "Steel for reinforcement of concrete shall meet the requirements of the standard specifications for steel reinforcement of the American Railway Engineering Association."

In addition to the above three authors of new books to be published have asked the authority of your Board of Direction to embody information contained in our Proceedings in their books.

From these instances it will be apparent that your work has attained such a value that information from it is now sought. The knowledge ought to spur us on to constant improvement.

During the past year the third edition of the Manual has been issued. The comments on this volume by members and others have been quite complimentary. These compliments are deserved by the committees, Mr. Edwin F. Wendt, the Reviewer, Prof. Pence, the Editor, and your Secretary, Mr. E. H. Fritch.

It is our sad task to announce that we have lost several of our fellow-members by death during the past year:

Benjamin Douglas, late Tunnel Engineer, Detroit River Tunnel Company, a charter member and an active worker on committees, was accidentally killed while inspecting a bridge in Brazil, South America.

W. D. Taylor, late Chief Engineer, Chicago & Alton Railroad, a brief sketch of whom was given in Bulletin 138.

Frank E. Simar, late Division Engineer, Canadian Northern Railway, at Duluth, Minn.

N. P. Curtis, late Instructor, University of Wisconsin, at Madison.

N. J. Gibbs, until recently engaged in construction work on the Panama Canal. He was accidentally killed at Tomkins Cove, N. Y.

H. Pierce, late Engineer of Construction of the Chesapeake & Ohio Railway.

Lewis Kingman, late Office Engineer of the National Railways of Mexico.

John S. Metcalf, President of John S. Metcalf Co., Chicago.

PROGRESS IN ENGINEERING WORKS.

The year 1911 has witnessed the continued progress, and in some cases the completion, of vast works of engineers. Governments, whether Federal, State or Municipal, continue their works in times of depressed business as well as in prosperous times, and, therefore, the three greatest government undertakings, the Panama Canal, the Catskill Aqueduct and the Erie Canal, have been pushed steadily forward.

Of these the Catskill Aqueduct, estimated to cost $162,000,000, is of high importance, for it is expected to carry ultimately the water supply for 20,000,000 people. It is a stupendous undertaking, measuring 92 miles in length, from the Ashokan Reservoir in the Catskill Mountains to New York City, and, in time, to be extended into Brooklyn and Staten Island. The daily delivery of water is to reach 500,000,000 gallons. In addition to the 55 miles of cut and cover, there will be 24 grade tunnels, aggregating 14 miles, 6 miles of steel pipe siphons and 17 miles of pressure tunnels, 7 in number. The pressure tunnels are circular, about 14 ft. diameter, and the one of greatest magnitude and difficulty is that under the Hudson at Storm King Mountain, 1,150 feet below the surface of the

ground. It was holed through last month in the presence of the Mayor of New York City and many others.

Another important government enterprise, which was brought to successful completion last March, is the Roosevelt Dam, in the canyon of the Salt River, about 70 miles east of Phoenix, Ariz., as it is for the purpose of impounding 418,000,000,000 gallons of water for irrigation. It is 276 feet high, with a crest length of 1,080 ft. It was begun in September, 1906, and was estimated to cost about $3,850,000. Owing to its isolation, the cement used was manufactured at the site in a mill especially constructed for the work. The cost per barrel was $1.96, whereas, if shipped in, it would have been $9 per barrel.

Notwithstanding the depression in business, the year witnessed the continued progress, and also the completion, of some magnificent engineering works in the railway world.

The erection of the enormous and palatial station of the New York Central Lines in New York City has been finally started, after carrying on since 1903 a large amount of preliminary work of excavation, track laying and office building. This work has embraced about 3,000,000 cu. yds. of rock excavation, carried on under great difficulties, about 250,000 cu. yds. of concrete and about 60,000 tons of steel.

The tracks are on two levels, the suburban, 20 in number, about 49 ft. below the street level, and the express or through tracks, 22 in number, 20 to 25 feet above them.

On June 4, 1911, the large new passenger station of the Chicago & Northwestern Railway in Chicago, costing about $24,000,000, was opened for service. Its style is Italian Renaissance, and it is built of gray Maine granite. The train shed has 16 tracks, and belt conveyors are used for conveying some of the incoming mail.

Identified with the name of one man, Henry M. Flagler, an enterprise entirely different from any other was brought to successful completion in the last week of December, 1911, so far as the placing of the last batch of concrete was concerned. This is the famous ocean railway from Miami to Key West in Florida, 154 miles, of which 74 miles are on land, 25 miles on swamps and 55 miles over water or on the long line of islands that make up the Florida Keys. There are about 500 reinforced concrete segmental and semi-circular arches from 45 to 60 ft. span. The longest viaduct is 10,500 ft., between Long Key and Conch Key. It is a wonderful piece of work and several disasters from storms during the construction have been experienced. It was opened for public service January 22, 1912.

Another great railroad enterprise, estimated to cost $9,500,000, is the line and grade improvement of the Delaware, Lackawanna & Western Railroad, between Slateford, Pa., and Hopatcong, N. J., which was opened for traffic Christmas, 1911. The old line was shortened from 39.57 miles to 28.45 miles, the grade reduced from 1.14 per cent. to .55 per cent., and the curvature from 6° 54′ to 2°, except in the case of one of 3½°, saving 1,560° of central angle. It was an unusually bold piece of work, and of

great magnitude. The grading consisted of 7,890,000 cu. yds. of earth excavation, 6,502,000 cu. yds. of rock excavation and 16,000,000 cu. yds. of embankment. The Pequest fill, containing 6,625,650 cu. yds. of material, is probably the largest railroad embankment ever constructed, being 3 miles long and from 75 ft. to 110 ft. high. The total quantity of concrete is 266,900 cu. yds., and two of the bridges are magnificent reinforced concrete arch viaducts, one over the Delaware River, and the other over the Paulins Kill. The first is 1,540 ft. long and 64 ft. high, and consists of five spans of 150 ft., two of 120, one of 53 and one of 50½ ft. The Paulins Kill viaduct is 1,100 ft. long and 117 ft. high, and has five spans of 120 ft. and two of 100 ft.

The Southern Pacific Railway also completed a line and grade change up the western slope of the Sierras from Rocklin, Cal., to Colfax, 30.8 miles on a 1.5 per cent. grade. There are 17 tunnels on the line

The Galveston Causeway, estimated to cost $1,615,000, was begun in 1909, and is a structure a little more than 2 miles long, connecting Galveston Island, on which the city of that name stands, with the mainland. its main feature being a reinforced concrete viaduct 2,455 ft. long, consisting of twenty-eight 70 ft. arch spans and a lift span with a clear waterway of 109 ft. The viaduct portion is 66 ft. wide, and carries 2 railroad tracks, one electric railway track and a roadway of 19 ft. clear width. On the causeway embankment approaches there are more tracks, and the roadway widens to 40 ft. About 9,808 concrete sheet piles, making a continuous strip 35 miles long, were required.

The work of introducing electric power on steam railroads was continued, although in this case, the Hoosac Tunnel, it was of but limited extent. The work was begun October 3, 1910, and finished May 18, 1911, at a cost of 1¼ millions. The electric system is the same as used by the New York, New Haven & Hartford, and the zone extends from a small tunnel just west of the North Adams Station to a point just east of the Hoosac Tunnel station, 21 miles of track being electrically operated. The tunnel is 4.75 miles long, and was opened in 1875. But lately the New Haven Company has made known its plan to change the main line from Stamford to New Haven to electric traction at an early date, at an estimated cost of $7,000,000.

Last April it was announced that a beginning had been made on the last of the $160,000,000 worth of improvements started in 1903 by the Pennsylvania Railroad Company, viz: the New York Connecting Railroad, which will link the Pennsylvania and New Haven roads together. This link will be 12 miles long, the principal feature of which will be the four-track bridge from Astoria on Long Island over Hell Gate, Ward's and Randall's Islands to Mott Haven or Port Morris. The bridge over Hell Gate and its approaches will be about 3 miles long, and will be of most massive construction, costing about $20,000,000. The main span is a steel arch 1,020 ft. long and 140 ft. above mean water level, making an imposing gateway for the East River entrance to New York Harbor.

Great engineering works are not confined to this country. The Swiss

railway engineers have been obliged, by the rugged nature of their country, to resort to long and ingenious tunnel building, in order to prevent their land from becoming a barrier to international transportation. The world's longest tunnels have been built there, the Simplon, 12.4 miles long; the St. Gothard, 9.5 miles long, and the past year witnessed the piercing of the third longest, the Loetschberg, 9 miles long. They also have the first, Mont Cenis, 7.5 miles long, begun in 1857, and the Arlberg, 6.5 miles long. In the case of many of these tunnels, gain in elevation in short distances has been obtained by the use of the spiral, making the journey over the railway most fascinating, interesting and beautiful.

The Loetschberg Tunnel is built to put the capital, Bern, on the main line from Milan, Italy, to Paris and Calais in France, while at the same time the distance is shortened by 80 miles to 675 miles. It was originally planned to be straight, but a disastrous inrush of water from the Kander River, burying 25 men, compelled the contractors to wall it up and build a detour with two short curves. The record of tunnel driving has been made in this work, a start being made November 1, 1906, while the headings met March 31, 1911.

The increased daily rate of tunnel driving due to improved methods and machinery is well illustrated in these Swiss tunnels.

The rate at the Mont Cenis, begun in 1857, was 7.75 ft. per day, two headings.

The rate at the St. Gothard, begun in 1872, was 18 ft. per day, two headings.

The rate at the Arlberg, begun in 1880, was 27.25 ft. per day, two headings.

The rate at the Simplon, begun in 1893, was 36 ft. per day, two headings.

The rate at the Loetschberg, begun in 1906, was 29.5 ft. per day, one heading, while a maximum for one day with one heading was 36 ft.

The Panama Canal continues to be the most costly and most stupendous enterprise now in progress, and its engineers are earning a monument of fame for themselves. The Special Commissioner to "The Engineer" of London, Mr. Percy F. Martin, F.R.G.S., who visited the Canal in 1910, makes this statement in the issue of June 9, 1911: "When the Canal shall be pronounced completed, and the huge lock gates swing open for the first time to receive the earliest vessel, a chorus of acclamation and congratulation will ascend such as probably no human achievement has ever yet called forth. And justifiably so."

In Engineering News for February 17, 1910, the following appeared:

THE COMPLETE ENGINEER OF 300 YEARS AGO.

"Wrapped in the stoutest of manila paper and deposited on the shelves of the library of the American Society of Civil Engineers is a book, the gift of Mr. W. A. Haven, M. Am. Soc. C. E., which is probably one of the earliest of printed books in the English language treating of the art of science of engineering. On a curiously embellished title page is the following caption:

"'A Practical Abstract of the Arts of Fortification and Assailing * * * Written for the benefit of such as delight in the Practice of those Noble Arts. By David Papillon Gent: * * * London Printed by R: Austin and are to be sould at the south side of the Exchange & in Popes head Alley 1645.'

"Engineering in that day, and for a century or so after, was entirely a military accomplishment, and so the science discussed by the author did not embrace any of the civil arts which were later a part of the engineer's knowledge, but prefacing the more serious work there is a chapter on (The True Character of a Complete Engineer) which will appeal even to the modern engineer. Especially will the last paragraph of this chapter touch a tender spot in the heart of every engineer who has had to argue against all reason with the lawyer, director or business man who can see in engineering only a superior sort of craftsmanship which, in its fundamentals, should be knowledge easily deduced by themselves. The major portion of this first chapter follow:

"'OF THE TRUE CHARACTER OF A COMPLETE ENGINEER.

"'(1) He is to be religious for the fear of the Lord is the beginning of wisdom.

"'(2) He is to be a souldier for none can better judge of the suffidiency or insufficiency of fortification. * * *

"'(3) He is to be a traveller; for he that hath not seen variety of works, and the excellency of foreign Fortifications, cannot perceive the defects of ours, nor give directions to rectify them.

"'(4) He is to be well versed in the Arithmetike for his calculations; in the Geometry, for the setting out of all superficies; in the Architecture, for to direct all manner of artificers; and in the other parts of the Mathematikes, for the taking of distances, depths and elevations, and for the inventing and contriving of all manner of Engines and machines.

"'(5) He is to be wise in all his proceedings, punctual in all his promises, careful and diligent in his calling, and rather inclined to austerity with lenity, or otherwise he will never be respected, served or obeyed.

"'(6) He is to be of solid judgment and quick of apprehension to judge aright of the defects and advantages of places. * * * He is not to give account of his actions to any, but to the Generall, or to the lieutenant Generall of the Ordnance if he be in an Army, or in a Garison, only to the grand Committee, and to the Governour; and as for all other kinds of men, inhabitants, souldiers or officers; he is not bound to expostulate the case, if they demand of him reasons for any thing he directs or commands to be done; neither ought he if he regards his reputation, and makes conscience of his ways, to comply * * * with the humour of the greatest in authority, or be led to assent to any resolution, that is against the maxims of his Art, by the Logical and Sophisticall reasons and arguments of Scholars or Church-men; for some of them are now a days overbusie in things that go beyond their element, and endeavor to over-sway Artists by rhetorike, considering not that their reasons are no reasons at all to the reasons of Art. And this last quality is the essentiall part of a good Engineer; for all the other are but to small purpose without this.'"

Fellow members: Many of the engineers engaged in the huge enterprises briefly outlined in the foregoing pages, and in other work, too, not mentioned, will measure up with "The Complete Engineer of 300 Years Ago." (Applause.)

The President:—I desire to read the following extract from a letter from Mr. Edwin F. Wendt, Chairman of the Publication Committee, as it gives additional information to that which I have given in the report:

"The work of the Publication Committee for the year may be considered as finished.

"The Secretary reports that the paper stock for Proceedings has been imported from Europe and is now in Chicago. The results from the use of this paper have been very satisfactory and the Secretary reports that all experience with this paper so far demonstrates the wisdom of its selection. It is particularly gratifying to know that it will be feasible and practical to bind the 1,600 pages of our Proceedings into one volume, which will be No. 13. The advantages of this practice will be:

"A saving in shelf room in libraries.

"The elimination of one volume of our Proceedings.

"A reduction in costs of binding.

"It is probable that the 1912 Proceedings will be available in paper binding by May 1. Cloth bound copies will likely be ready June 1. When our next Proceedings have been issued and all of our printing bills have been paid, the Board of Direction will have reason to congratulate itself by reason of the reduction in expenses of printing, binding and mailing. The Secretary, as usual, has followed this work in detail with the greatest care and we are fortunate in having as Secretary a man who is capable, energetic and loyal in the highest degree.

"Another subject needs some comment at this time. Our Advertising Representative has not been successful in making contracts for advertising, either for the Bulletins or the Official Program of the Convention. This is a matter for regret as we had confidently calculated upon a net return from the Program, especially. After a conference between the Advertising Representative and Mr. Fritch, it was decided by the Secretary and myself that it would be proper, and even satisfactory to the Advertising Representative, for the Secretary to make his usual effort to obtain advertising for the Program which will be issued this week before the Convention."

The President:—The next order of business is the Secretary's and Treasurer's reports.

(Secretary E. H. Fritch then read the following reports:)

SECRETARY'S REPORT.

To the Members of the American Railway Engineering Association:

I have the honor to present the following report for the period ending December 31, 1911, and from January 1, 1912, to March 15, 1912:

MEMBERSHIP.

Total Membership at last annual convention, March 15, 1911		967
Additions during the year, 95		95
		1,062
Deceased Members	7	
Withdrawals during the year	13	
Dropped for non-payment of dues	12	
	32	32
Total membership March 15, 1912		1,030

Consisting of:

Members	939
Honorary Members	4
Associates	87
	1,030

GEOGRAPHICAL DISTRIBUTION.

The geographical distribution of the membership is indicated in the following table:

United States	899	Korea	1
Dominion of Canada	83	Panama	1
Mexico	9	Australia	1
Cuba	5	Great Britain	1
China	6	Peru	2
New Zealand	4	Russia	1
Philippine Islands	3	Central America	2
India	2	Porto Rico	1
Bolivia	1		
Japan	3	Total	1,030

CLASSIFICATION OF MEMBERS.

Presidents	22	Master Carpenters	2
Assistant to President	2	Rail Expert	1
Vice-Presidents	27	Supt. Bridges and Buildings	9
General Managers	20	Supervisors	2
Dir. Maint. and Operation	1	Resident Engineers	36
Asst. General Managers	8	Signal Engineers	18
General Superintendents	16	Assistant Signal Engineer	1
Asst. General Superintendent	1	Managers Timber Dept	6
Division Superintendents	38	Chief Timber Inspector	1
Chief Engineers	121	Forester	3
Asst. Chief Engineers	16	Contracting Engineers	13
Principal Asst. Engineers	14	Supervisor Materials	1
Chief Eng. Maint. of Way	6	Chemists and Engineers Tests	4
Asst. Chief Eng. M. of Way	5	Metallurgical Engineers	4
Engineers of Construction	14	Professors in Colleges	19
Engineers Maint. of Way	86	Associate Professors	16
Bridge Engineers	27	Civil Engineers	50
Engineers Surveys	1	Consulting Engineers	89
Division Engineers	86	General Foreman Water Works	1
Assistant Engineers	111	Engineer Grade Elimination	4
District Engineers	13	Purchasing Agent	1
Electrical Engineers	2	Receivers	3
Inspecting Engineers	14	Editors	3
Supervising Engineers	1	Inspector Maintenance	3
Architects	4	Masonry Engineer	1
Locating Engineers	3	Asst. Superintendents	2
Engineers Track Economics	1	Engineers Valuation	2
Engineers Track and Roadway	4	Drainage Engineer	1
Maintenance of Way Acct	1	General Agent	1
Engineers Bridges and Bldgs.	7	Engineer Water Service	1
Office Engineers	5	Municipal Engineers	6
Chief Draftsmen	4	Commercial Engineer	1
General Roadmasters	2	Miscellaneous	26
Roadmasters	16	Totals	1,030

PUBLICATIONS.

During the year the following publications have been issued by the Association:

12 Bulletins.
Proceedings for 1911 (Parts 1 and 2).
1 Edition of the Manual.
2 Editions of Specifications for Plain and Reinforced Concrete and Steel Reinforcement.
1 Edition of Conventional Signs.
Program for the Thirteenth Annual Convention

The table below indicates the number of pages, illustrations, etc., of the publications issued:

	No. Pages.	Half-Tones.	Folding Plates	Diagrams.	Tables.	Forms.
Bulletins	1740	440	20	240	351	...
Proceedings	1352	82	8	306	219	...
Manual	525	55	5	264	44	42
Steel Specifications.	34	...	...	3	2	...
Concrete Specific..	15	...	...	1	1	1
Conventional Signs	15	30	...	110	...	...
Program	56	...	...	...	...	...
	3737	607	33	924	617	43

FINANCIAL STATEMENT.

Balance cash on hand March 15, 1911 ..... $13,216.62

Consisting of:

Ten Railroad Bonds, as follows: Four St. Louis Southwestern Railway Company Bonds, par value $1,000 each, at cost	$ 3,319.31	
Six Lake Shore & Michigan Southern Railway Company Bonds, par value $1,000 each, at cost	5,660.25	
Cash in bank	4,237.06	
		$13,216.62

Receipts during the year:

	March 16, 1911, to Dec. 31, 1911.	Jan. 1, 1912, to Mar. 15, 1912.	Totals for One Year.
From Members, dues, etc	$ 5,274.48	$ 8,567.35	$13,841.83
From Others, sales of publications, advertising, etc.	6,853.59	1,394.91	8,248.50
From American Railway Association, account Rail Committee Expense.	6,495.57	508.56	7,004.13
From Interest	295.72	67.62	363.34
From Loan	1,000.00	.....	1,000.00
From Proceeds of Sale of Bonds	3,797.33	.....	3,797.33
Totals	$23,716.69	$10,538.44	$34,255.13

Expenditures during the year:

March 16, 1911, to Dec. 31, 1911	$26,650.64
January 1, 1912, to March 15, 1912	2,719.02
Total Expenditures	$29,369.66

Summary.

	March 16, 1911, to Dec. 31, 1911.	Jan. 1, 1912, to Mar. 15, 1912.	
Receipts	$23,716.69	$10,538.44	$34,255.13
Expenditures	26,650.64	2,719.02	29,369.66
Total			$ 4,885.47
Less amount of proceeds from sale of bonds			3,797.33
Net Excess of Receipts over Expenditures			$ 1,088.14

EXPENDITURES IN DETAIL.

Items.	March 16, 1911, to Dec. 31, 1911.	Jan. 1, 1912, to Mar. 15, 1912,	Totals for One Year.
Stationery and Printing	$ 298.20	$ 66.66	$ 364.86
Proceedings	4,842.18	.25	4,842.43
Bulletins	4,151.61	366.54	4,518.15
Manual	2,187.79	.....	2,187.79
Postage	784.20	189.87	974.07
Salaries	3,593.30	746.66	4,339.96
Officers Expenses	19.00	16.50	35.50
Annual Meeting	1,220.93	.....	1,220.93
Telephone and Telegrams	67.41	20.24	87.65
Rents	600.00	120.00	720.00
Expressage	524.46	28.53	552.99
Exchange	23.20	2.40	25.60
Supplies	220.06	36.18	256.24
Light	12.79	6.15	18.94
Miscellaneous	75.91	9.85	85.76
Badges	.....	80.00	80.00
Commission on Advertising	.....	76.25	76.25
Impact	1,048.96	.....	1,048.96
Rail Committee	5,850.70	936.26	6,786.96
Committee Expenses	117.44	16.68	134.12
Repayment of Loan	1,000.00	.....	1,000.00
Interest on Loan	12.50	.....	12.50
Total	$26,650.64	$2,719.02	$29,369.66

Respectfully submitted,

E. H. FRITCH, Secretary.

TREASURER'S REPORT.

To the Members of the American Railway Engineering Association:

I have the honor of presenting the following report:

Balance Cash on hand, March 15, 1911		$13,216.62
Consisting of:		
Ten railroad bonds, as follows: Four St. Louis Southwestern bonds, par value, $1,000 each, at cost	$ 3,319.31	
Six L. S. & M. S. Ry. bonds, par value, $1,000 each, at cost	5,660.25	
Cash in Bank	4,237.06	
Total		$13,216.62
Receipts from all sources, March 16, 1911, to Dec. 31, 1911		$23,716.69
Receipts from all sources, Jan. 1, 1912, to March 15, 1912		10,538.44
Total Receipts for the year		$34,255.13

Expenditures:

	March 16, 1911, to Dec. 31, 1911.	Jan. 1, 1912, to Mar. 15, 1912.	
Paid on audited vouchers	$25,602.96	$ 3,766.70	$29,369.66
Balance to credit			$ 4,885.47
Less proceeds from sale of four L. S. & M. S. bonds			3,797.33
Net Excess of Receipts over Expenditures			$ 1,088.14

Composition of Balance, March 15, 1912:

Cash in bank	$ 8,836.43
Cash on hand, checks, etc	286.10
Four St. Louis Southwestern bonds, at cost	3,319.31
Two L. S. & M. S. bonds, at cost	1,886.75
Total Cash Assets, March 15, 1912	$14,328.59

The bonds above listed are registered in the name of the Association and have been placed in a safety deposit box in the Merchants' Loan and Trust Company's vaults, Chicago.

Respectfully submitted,

GEO. H. BREMNER, Treasurer.

The President:—What is your pleasure in regard to the reports of the Secretary and the Treasurer?

Mr. W. H. Elliott:—I move the acceptance of the reports.

(The motion was carried.)

The President:—There has been prepared for our benefit by the National Railway Appliances Association an unparalleled exhibit of rail-

way appliances in the Coliseum, on Wabash Avenue, and in order to allow the members time to visit it, it has been decided to adjourn at 4 p. m. to-day. The exhibit is more complete and larger than ever, so that it has been necessary to use the adjacent armory building this year.

There will be no evening session.

The members are requested, as usual, to be early in the purchase of dinner tickets, which will be on sale this afternoon in the lobby outside of this room. You all know, from what has been said in previous years, that we have to give the necessary information to the hotel people in order that they may make the necessary preparations.

The next order of business is the presentation of the reports of the Standing and Special Committees. The members of committees will please take their places on the platform when their names are called by the Secretary. If all the reports assigned for any one day are finished before the time of adjournment, the first report assigned for the following day may be brought before the Association in order to advance the work of the convention.

We will now take up the report of the Committee on Rules and Organization. Mr. Jos. O. Osgood, the Chairman of the Committee, at the last minute was prevented from coming here, so that he has not had an opportunity to fully instruct the other members of his Committee as to the preliminary announcement. Mr. F. D. Anthony will be kind enough to state the general work of the Committee in order that the report of the Committee may be discussed.

(The report of the Committee on Rules and Organization was presented by Mr. F. D. Anthony, a member of the Committee. See report, pp. 65-68; discussion, pp. 919-931.)

The President: The next report is that of the Committee on Signals and Interlocking, of which Mr. A. H. Rudd is Chairman. In the absence of the Chairman, Mr. L. R. Clausen, the Vice-Chairman, will present the report.

(The report of the Committee on Signals and Interlocking was presented by Mr. L. R. Clausen, the Vice-Chairman. See report, pp. 69-76; discussion, pp. 932, 933.)

The President:—The next report is that of the Committee on Iron and Steel Structures, of which Mr. C. H. Cartlidge is Chairman. We will ask the Chairman of the Committee to make the opening statement.

(The report of the Committee on Iron and Steel Structures was presented by Mr. C. H. Cartlidge, the Chairman. See report, pp. 81-88; discussion, pp. 934-945.)

AFTERNOON SESSION.

The President:—The report of the Committee on Wooden Bridges and Trestles will next be disposed of. Mr. C. C. Wentworth, the Chairman, will make the opening statement.

(The report of the Committee on Wooden Bridges and Trestles was presented by Mr. C. C. Wentworth, the Chairman. See report, pp. 71-80; discussion, page 946.)

The President:—The next report is that of the Committee on Ballast, of which Mr. H. E. Hale is Chairman. The Chair will ask Mr. Hale to make the opening statement.

(The report of the Committee on Ballast was presented by Mr. H. E. Hale, the Chairman. See report, pp. 95-300; discussion, pp. 949, 950.)

The President:—The next report is that of the Committee on Ties, of which Mr. L. A. Downs is Chairman. Mr. Downs will make the opening statement for the Committee.

(The report of the Committee on Ties was presented by Mr. L. A. Downs, the Chairman. See report, pp. 301-370; discussion, pp. 951-964.)

The President:—The next report is that of the Committee on Track, of which Mr. J. B. Jenkins is Chairman. Mr. Jenkins will make the preliminary statement for the Committee.

(The report of the Committee on Track was presented by Mr. J. B. Jenkins, the Chairman. See report, pp. 371-386; discussion, pp. 965-980.)

The President:—We will now adjourn, and the remaining questions will be taken up in the morning on the length of switches and also the specifications.

(Adjourned until 9 o'clock a. m., Wednesday.)

WEDNESDAY, MARCH 20, 1912.

MORNING SESSION.

The President:—Before taking up the regular order of business, the Chair would ask the unanimous consent of the Association to vary slightly from the program in order to be able to announce the results of the election of officers at the close of the afternoon session. The Chair will appoint as Tellers the following members: C. H. Spencer, C. H. Fisk and W. J. Bergen. The Secretary will turn over the ballots to the Tellers after the noon adjournment. The Tellers will retire to the anteroom and prepare their report. The polls will close at twelve o'clock to-day. This room has been engaged for some banquet this evening, and as an accommodation to the hotel they would like to have us adjourn between four-thirty and five o'clock if we can possibly do so, in order that they may have the room so as to prepare for the banquet.

This evening our annual dinner is to commence promptly at seven o'clock, and the members are urgently requested to be at the banquet hall before seven o'clock, so that we can begin promptly at seven.

The further consideration of the report of the Committee on Track will now be taken up. The consideration of the report was suspended last evening while we were discussing conclusion 3 on page 374, with reference to the lengths of switches and number of frogs, and this question is now

open for discussion. Mr. Jenkins, the Chairman of the Committee, will continue the presentation of the report.

The next report is that of the Committee on Yards and Terminals, of which Mr. C. H. Spencer is Chairman. The Chairman will make the preliminary announcement.

(The report of the Committee on Yards and Terminals was presented by Mr. C. H. Spencer, the Chairman. See report, pp. 89-92; discussion, pp. 947, 948.)

The President:—The next report is that of the Committee on Rail, Mr. Chas. S. Churchill, Chairman. The Chairman is requested to make the preliminary statement.

(The report of the Committee on Rail was presented by Mr. Chas. S. Churchill, the Chairman. See report, pp. 559-862; discussion, pp. 1017-1038.)

The President:—The next report is that of the Committee on Roadway. In the absence of the Chairman, Mr. W. M. Dawley, the Vice-Chairman, will make the preliminary statement.

(The report of the Committee on Roadway was presented by Mr. W. M. Dawley, the Vice-Chairman. See report, pp. 387-400; discussion, pp. 981, 982.)

The President:—The next Committee is that on Water Service, Mr. Robert Ferriday, Chairman. The Chairman will make the opening remarks in regard to the report.

(The report of the Committee on Water Service was presented by Mr. Robert Ferriday, the Chairman. See report, pp. 421-428; discussion, pp 983-988.)

AFTERNOON SESSION.

The President:—The next report is that of the Committee on Masonry, of which Mr. Geo. H. Tinker is Chairman. Mr. Tinker will make the opening statement.

(The report of the Committee on Masonry was presented by Mr. Geo. H. Tinker, the Chairman. See report, pp. 459-504; discussion, pp. 990-995.)

The President:—The next report is that of the Committee on Records and Accounts, of which Mr. H. J. Pfeifer is Chairman. The Chairman will make the preliminary statement.

(The report of the Committee on Records and Accounts was presented by Mr. H. J. Pfeifer, the Chairman. See report, pp. 505-507; discussion, pp. 946, 947.)

The President:—The next report is that of the Committee on Electricity, of which Mr. George W. Kittredge is Chairman. Mr. Kittredge will make the preliminary statement for the Committee.

(The report of the Committee on Electricity was presented by Mr. George W. Kittredge, the Chairman. See report, pp. 509-558; discussion, pp. 998-1016.)

The Chair expected to announce the result of the election to-night, but the Committee is still counting the ballots and he will, therefore, be unable to do so until to-morrow.

Some members have expressed a desire to visit the cement plants at Buffington and the steel plants at Gary, Indiana. Arrangements have been made for a trip of inspection Friday morning.

No more reports will be taken up this evening, and a motion to adjourn is in order.

(On motion the meeting was adjourned until 9 a. m., Thursday.)

THURSDAY, MARCH 21, 1912.

MORNING SESSION.

The President:—The first business this morning will be the report of the Committee on Conservation of Natural Resources, Mr. E. O. Faulkner, Chairman. In the absence of Mr. Faulkner, the report will be presented by Mr. William McNab, the Vice-Chairman.

(The report of the Committee on Conservation of Natural Resources was presented by Mr. William McNab, the Vice-Chairman. See report, pp. 429-458; discussion, page 989.)

The President:—The next report is that of the Committee on Signs, Fences and Crossings, Mr. C. H. Stein, Chairman.

(The report of the Committee on Signs, Fences and Crossings was presented by Mr. C. H. Stein, the Chairman. See report, pp. 900-904; discussion, pp. 1055-1057.)

The President:—The next report is that of the Committee on Buildings, of which Mr. Maurice Coburn is Chairman. Mr. Coburn will make the opening statement.

(The report of the Committee on Buildings was presented by Mr. Maurice Coburn, the Chairman. See report, pp. 885-889; discussion, page 1054.)

The President:—The Committee on Uniform General Contract Forms will please come forward. Mr. W. G. Atwood, the Vice-Chairman, will make the statement of the work of this Committee.

(The report of the Committee on Uniform General Contract Forms was presented by Mr. W. G. Atwood, the Vice-Chairman. See report, pp. 907-916; discussion, pp. 1059-1076.)

The President:—The next report is that of the Committee on Economics of Railway Location), of which Mr. A. K. Shurtleff is Chairman. Mr. Shurtleff will make the opening statement.

(The report of the Committee on Economics of Railway Location was presented by Mr. A. K. Shurtleff, the Chairman. See report pp. 905, 906; discussion, page 958.)

The President:—The next Committee is the Special Committee on Grading of Lumber, Dr. Hermann von Schrenk, Chairman. We will hear from Dr. von Schrenk.

(The report of the Special Committee on Grading of Lumber was presented by Dr. Hermann von Schrenk, the Chairman. See report, pp. 873-884; discussion, pp. 1052, 1053.)

The President:—The next report is the Committee on Wood Preservation. Mr. Earl Stimson is the Chairman. We will have the opening statement by Mr. Stimson.

(The report of the Committee on Wood Preservation was presented by Mr. Earl Stimson, the Chairman. See report, pp. 863-872; discussion, pp. 1039-1051.)

The President:—We have finished the business in connection with the reports of Special and Standing Committees, and under the heading of "New Business" there are some resolutions to be offered.

Mr. J. B. Berry (Chicago, Rock Island & Pacific):—I would suggest action by the members of this Association on the following resolutions:

"Resolved, by the members of the American Railway Engineering Association in convention assembled, that we desire to place on record our hearty appreciation of the efforts made and the admirable results obtained by the Railway Age Gazette in its daily issue during this convention.

"Resolved, that the cordial thanks of the Association be extended to its managing officers and editorial staff.

"Resolved, that a copy of these resolutions be spread upon the Minutes of this convention and a copy transmitted to the Railway Age Gazette."

I submit the foregoing resolutions for adoption by the Association.

(The resolution was unanimously adopted.)

Mr. Berry:—I offer the following resolutions:

"Resolved, by the members of the American Railway Engineering Association in convention assembled, that we desire to place on record our hearty appreciation of the efforts made and the admirable results obtained by the Railway and Engineering Review in its daily issue during this convention.

"Resolved, that the cordial thanks of the Association be extended to its managing officers and editorial staff.

"Resolved, that a copy of these resolutions be spread upon the Minutes of this convention and a copy transmitted to the Railway and Engineering Review."

(The resolution was unanimously adopted.)

Mr. Chas. S. Churchill (Norfolk & Western):—I offer the following resolutions:

"Resolved, by the members of the American Railway Engineering Association, in convention assembled, that we desire to place on record our appreciation of the efforts made by the National Railway Appliances Association in making possible the most admirable and instructive exhibit of devices and materials used in the construction, operation and maintenance of railways, and of the educational value of the exhibition.

"Resolved, that the thanks of the members of this Association be extended to the officers and members of the National Railway Appliances Association for courtesies and facilities placed at our disposal during the convention.

"Resolved, that a copy of these resolutions be forwarded to the officers of the National Railway Appliances Association, and that they be spread upon the Minutes of this convention."

(The resolutions were unanimously adopted.)

Mr. Edwin F. Wendt (Pittsburgh & Lake Erie) :—I offer the following resolution:

"Resolved, that the hearty thanks of the members of the American Railway Engineering Association in convention assembled be tendered to the Official Reporters, Messrs. T. E. Crossman and G. W. Burgoyne, for their efficient and accurate report of the Proceedings of this convention, and that a copy of this resolution be spread upon the Minutes and a copy transmitted to them."

(The resolution was unanimously adopted.)

Mr. C. H. Stein (Central Railroad of New Jersey) :—I offer the following resolution for adoption:

"Resolved, that the hearty thanks of the members of the American Railway Engineering Association in convention assembled be tendered the Tellers, Messrs. C. H. Spencer, C. H. Fisk and W. J. Bergen, for their arduous labor and for the efficient manner in which the work has been performed."

(The resolution was unanimously adopted.)

Mr. A. F. Robinson (Santa Fe) :—I offer the following resolution:

"Resolved, that the hearty thanks of the members of the American Railway Engineering Association in convention assembled be extended and are hereby tendered the Committee on Arrangements for the efficient manner in which all details for this convention have been carried out.

"Resolved, that the Committee be 'continued at the same salary.' "

(The resolution was unanimously adopted.)

The President:—I will ask the Secretary to announce the election of officers for the ensuing year, and I desire to say that we have imposed on the Tellers this time. They were all afternoon yesterday and long into the evening counting the votes, and we are, therefore, under obligations to the Committee at this time for the care and labor used in the preparation of their report.

The Secretary:—The report of the Tellers is as follows:

REPORT OF TELLERS.

To the Members of the American Railway Engineering Association:

We, the undersigned, appointed Tellers to canvass the votes cast for the election of officers, Board of Direction and Nominating Committee for the year 1912, beg leave to advise that after careful examination and canvass of each ballot the results are as follows:

Total vote cast	517	
Unsigned ballots	12	
Associate members not counted	20	32
Total vote counted		485

President:
C. S. Churchill....483
A. W. Thompson.... 1
Blank 1

Vice-President:
W. B. Storey, Jr....482
J. B. Berry.... 1
A. S. Baldwin.... 1
Robert Trimble 1

Treasurer:
Geo. H. Bremner....485

Secretary:
E. H. Fritch....485

Directors for 3 Years:
F. A. Delano....238
W. L. Darling....236
W. B. Scott....188
C. H. Cartlidge....182
C. C. Anthony....141
S. B. Fisher....131
W. S. Kinnear....117
C. H. Ewing....109
J. M. R. Fairbairn.... 88
J. G. Sullivan.... 1

Nominating Committee:
F. L. Stuart....330
C. F. W. Felt....307
J. O. Osgood....267
G. J. Ray....249
F. H. Alfred....241
A. K. Shurtleff....224
C. E. Lindsay....216
W. Beahan 203
A. W. Newton....148
C. L. Ransom....125
A. O. Cunningham.... 1
J. F. Coleman.... 1
J. G. Sullivan.... 1

Respectfully submitted,

C. H. SPENCER,
C. H. FISK,
W. J. BERGEN,
Tellers.

The Secretary—The result of the ballot for officers is as follows:

President—Chas. S. Churchill.

Vice-President—W. B. Storey, Jr.

Treasurer—Geo. H. Bremner.

Secretary—E. H. Fritch.

Three Directors (three years each)—W. L. Darling, F. A. Delano, W. B. Scott.

Five Members of Nominating Committee—Francis Lee Stuart, C. F. W. Felt, Jos. O. Osgood, G. J. Ray, F. H. Alfred.

The President:—Gentlemen, in relinquishing the office of President, I desire to express my profound appreciation of the honor and favor you have done me in electing me to that office for the past year. I now take pleasure in asking Mr. McDonald and Mr. Wendt to escort the newly-elected President to the platform.

President-Elect Churchill:—Gentlemen, I have always considered a membership on any Committee of this working association to be a position of distinct trust and prestige, and any official position as an honor. I, therefore, am very grateful for this highest honor that you have conferred upon me in making me the President of this Association, which now stands so high in the railway matters of the world.

I thank you. I appreciate the fact that in taking this office after such brilliant stars who have preceded me that I need all the help that the committees and members can give, and I am sure that I will have it, and you shall have my best efforts in everything that we are called upon to carry out.

In my last word I want to call attention to the recommendation of the outgoing President:—that we try to increase the membership for the specific object at this time of increasing the revenues of the Association. There are many matters before this Association that could be looked into further than we are now able to look into them, and experiments which could be carried on which we are now unable to make, because of a lack of sufficient funds. If each member of this Association will leave this assembly with the idea that he will try to bring into the Association during this year more new members, we will in the course of a year or so have the revenue from the membership dues which we require.

This, I believe, is all the business before this convention.

Mr. L. C. Fritch (Chicago Great Western):—Mr. President, I wish to offer the following resolution:

"Resolved, by the members of the American Railway Engineering Association in convention assembled, that we desire to place on record our hearty appreciation of the well-directed and untiring efforts and eminently efficient administration of the retiring President, Mr. W. C. Cushing, and that this resolution be spread upon the Minutes of the meeting and a copy transmitted to Mr. Cushing."

(The question on the adoption of the resolution was put by Mr. J. B. Berry, and was unanimously adopted.)

Past-President Cushing:—I thank you.

The President:—I wish to announce a meeting of the Board of Direction in Room 1166, at two o'clock.

The convention is adjourned to March, 1913.

E. H. Fritch, Secretary.

COMMITTEE REPORTS

REPORT OF COMMITTEE XII—ON RULES AND ORGANIZATION.

Jos. O. Osgood, *Chairman;*
F. D. Anthony.
J. B. Carothers.
S. E. Coombs.
J. B. Dickson.
C. Dougherty.
J. A. Gordon.
G. D. Brooke, *Vice-Chairman;*
F. P. Gutelius.
Kenneth Hanger.
Jos. Mullen.
F. L. Nicholson.
W. C. Smith.
Committee.

To the Members of the American Railway Engineering Association:

Your Committee on Rules and Organization respectfully submits herewith its report, as follows:

Meetings of the Committee, Sub-Committees and Chairmen of the Sub-Committees were held as follows: A meeting of the Committee was held in New York, June 9, 1911; Sub-Committee meetings were held in New York and Chicago on July 21, and in Montreal on July 31, 1911; three Chairmen of Sub-Committees held a meeting in New York on September 8, 1911.

Last year's report of this Committee embodied revisions of the rules as then published in the Manual and additional rules of the same general character, all relating to the government of employes of the Maintenance of Way Department.

For this year's work your Committee was instructed by the Board of Direction to:

(1) Continue the compilation of rules for the government of Maintenance of Way employés.

(2) Formulate rules in the nature of specifications or instructions regarding the conduct of work, making use of the recommendations of the various Committees dealing with these subjects and of the best practice of railway companies, as embodied in their books of rules.

Some progress has been made with rules falling under the first of the instructions, but this year's report deals only with the work falling under the second of the instructions.

Your Committee recommends:

(1) That no change be made in the General Rules for the Government of Employés of the Maintenance of Way Department heretofore adopted by the Association.

(2) That to the rules heretofore adopted by the Association be added instructions, as follows:

*INSTRUCTIONS.

Cross-Sections.

(1) The roadbed, ballast and track shall conform to the standard plans. No changes in the sections shown shall be made without proper authority.

(Note: It is understood that cross-sections for wet cuts will be included in the standard plans.)

Drainage.

(2) All ditches, including intercepting ditches on the upper side of cuts, must be kept clean.

(3) Where heaving or wet spots develop, special drainage shall be provided.

Ballasting.

(4) Before re-ballasting track, line and grade stakes shall be set by the Engineer. All unsuitable material shall be removed and the roadbed widened to proper section, the waste material being used to widen banks, or otherwise, as may be directed.

(5) Track must be kept in good line and surface while ballasting, open track avoided as far as practicable, and such track carefully watched.

(6) After ballast is distributed it shall be trimmed, and the track lined and surfaced to conform to the standard plans.

(7) Where track is bonded, ballast must be kept at least one inch below the base of rail. At road crossings, platforms, etc., where this is not practicable, only clean gravel or rock ballast shall be used.

Ties.

(8) Ties stored along right-of-way shall be piled to conform to the standard plan.

(Note: The standard plan should show the minimum distance to the nearest rail.)

(9) The ties in track must be inspected at stated times each year and those which will not last until the next inspection marked for renewal.

(10) The renewal of ties shall be started when directed by the .....(Title)..... When ties are being renewed, the line and surface shall be corrected and ballast trimmed.

(11) All defective ties removed from track shall each day be placed for burning or loading on cars.

(12) The .....(Title)..... shall frequently inspect ties removed from track to see if any have been removed which might have remained in the track with safety until the next inspection.

(13) Ties shall be spaced according to the standard plans. All ties shall be placed square to the line of rails. The outside ends on double tracks, and the ends on one side throughout on single track, must be lined parallel with the rail.

(14) The heart side of ties must be turned down. The largest and

*For amendments to Clauses 6, 7, 10, 12 and 14, see Index.

best ties shall be selected for use at joints. Twisted or badly hewn ties must not be notched, but the bearings must be made true with the adze.

(15) Whenever spikes are drawn from ties, wooden tie plugs must be driven into all holes except in ties which are to be renewed that season. In replacing spikes they should be driven into the plugs.

Rail.

(16) In unloading rails from cars they should be skidded or otherwise carefully lowered to avoid injury. Where it is necessary to drop them, both ends must be dropped together and the greatest care taken to avoid their falling on hard and uneven surfaces.

(17) The bottom of the new rail and the bearing surface of the tie shall be cleaned before the new rail is laid.

(18) When replacing rail with rail of the same section, only two rows of spikes shall be drawn; in replacing with rail of a different section, three rows of spikes shall be drawn.

(19) In laying new rail, standard expansion shims shall be used. The temperature of the rail shall be taken by placing the thermometer on the rail. The openings between 33 ft. rails shall be as follows:

Temperature (Fahrenheit).	*Amount of Opening.*
—20° to 0°	5/16 in.
0° to 25°	1/4 in.
25° to 50°	3/16 in.
50° to 75°	1/8 in.
75° to 100°	1/16 in.

Over 100° to be laid close.

The rail should be laid without bumping and when practicable, laid rail by rail.

(20) The rails shall be brought squarely into line and at least two bolts tightened before spiking. All joint bars shall be securely fastened with the full number of bolts, tightening those at the center first. At permanent connections of rails of different sections step chairs and off-set splices must be used.

(21) All spikes must be driven vertically with the face in contact with the base of the rail. They should not be straightened while being driven. The rail must be full spiked and the spikes staggered so that the outside spikes shall be on the same side of the tie and the inside spikes on the opposite side.

(22) In making temporary connections in main tracks an old rail should be cut and fastened to the new rail, using compromise joints when necessary. Switch points shall be used for this purpose only during the presence of the Track Foreman.

(23) After new rail is laid the track must be lined and surfaced.

(24) All kinked or crooked rails must be straightened before being laid; if bent in service they must either be removed or straightened.

(25) Rails for curves of 2 degrees and over should be curved before being laid. In curving or straightening rails, the rail bender must be used.

*For amendments to Clauses 17, 18, 20 and 25, see Index.

Surfacing.

*(26) When surfacing (picking up low points or other low places), the general level of the track must not be disturbed.

NEXT YEAR'S WORK.

(3) For next year it is recommended that the Committee continue this year's work.

Respectfully submitted,

COMMITTEE ON RULES AND ORGANIZATION.

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*For amendment to Clause 26, see Index.

REPORT OF COMMITTEE X—ON SIGNALS AND INTERLOCKING.

A. H. Rudd, *Chairman;*
Azel Ames.
C. C. Anthony.
H. Baker.
H. S. Balliet.
W. B. Causey.
C. A. Christofferson.
C. E. Denney.
W. J. Eck.
W. H. Elliott.
G. E. Ellis.
W. J. Harahan.
M. H. Hovey.
L. R. Clausen, *Vice-Chairman;*
A. S. Ingalls.
J. C. Mock.
F. P. Patenall.
J. A. Peabody.
Frank Rhea.
W. B. Scott.
A. G. Shaver.
T. S. Stevens.
H. H. Temple.
Edwin F. Wendt.
J. C. Young.
Committee.

To the Members of the American Railway Engineering Association:

During the past year your Committee has met as follows: At Buffalo, May 25; Buffalo, June 29; Buffalo, July 27.

The Board of Direction assigned four subjects for consideration:

(1) Continue investigation of outline and description of a comprehensive and uniform signal system, suitable for general adoption, conferring with proper committee of the American Railway Association.

(2) Revise mechanical interlocking specifications, and include wrought-iron pipe as well as steel.

(3) Revise electric interlocking specifications and submit statement of the results from experience.

(4) Report on the effect of treated and metal ties on track circuits.

Last year your Committee presented revised specifications for various kinds of insulated wire, which the Association adopted. In order to bring these specifications into conformity with those adopted by the Railway Signal Association, a new insulation resistance table is herewith submitted with the following:

CONCLUSION.

(1) The following table of insulation resistances in megohms per mile at sixty (60) degrees Fahrenheit for the various thicknesses of insulation in fractions of an inch and the various sizes of wire is made a part of the specifications for mineral matter, rubber compound, insulated signal wire for current of 600 volts or less, appearing in Vol. 12, Part 1,

pp. 101 to 104, inclusive, and the insulation resistance in megohms per mile, shown on page 108, is revised to conform with this table.

B. & S. G.	3/64	2/32	5/64	3/32	7/64	4/32	5/32	6/32	7/32	8/32
0	....	....	900	1100	1200	1300	1500	1800	2000	2200
1	....	....	1000	1200	1400	1500	1800	1900	2200	2400
2	....	1000	1100	1400	1500	1600	1900	2200	2300	2600
3	....	1100	1200	1500	1600	1800	2000	2300	2600	2700
4	....	1200	1400	1600	1800	1900	2200	2400	2700	2800
5	....	1300	1500	1700	1900	2000	2300	2600	2800	3100
6	....	1400	1600	1800	2000	2200	2600	2800	3100	3400
8	1400	1600	1900	2200	2300	2600	2800	3200	3500	3800
9	1500	1800	2000	2300	2600	2700	3100	3400	3600	3900
10	1600	1900	2200	2400	2700	3000	3200	3600	3900	4200
12	1800	2200	2500	2800	3100	3200	3600	4000	4300	4600
14	2200	2600	2800	3200	3500	3600	4200	4400	4800	5100

(2) The above table of insulation resistances in megohms per mile at sixty (60) degrees Fahrenheit for the various thicknesses of insulation in fractions of an inch and the various sizes of wire is made a part of the specifications for mineral matter, rubber compound, insulated aerial braided cables for current of 660 volts or less, shown on pp. 105 to 109, inclusive, of the same Volume, and the insulation resistance megohms per mile, shown on page 108, is revised to conform thereto.

(3) The above table of insulation resistances in megohms per mile at sixty (60) degrees Fahrenheit for the various thicknesses of insulation in fractions of an inch and the various sizes of wire is made a part of the specifications for mineral matter, rubber compound, insulated, lead-covered, armored submarine cables for 600 or lower voltage service, shown on pp. 110 to 114, inclusive, of the same Volume, and the insulation resistance megohms per mile, shown on page 113, is revised to conform thereto.

Your Committee does not report this year on subjects Nos. 2, 3 or 4, assigned by the Board of Direction. It reports on Subject No. 1 as follows:

UNIFORM SIGNALING.

This subject was referred to the Committee on Transportation of the American Railway Association by the 1910 convention. In 1911, progress was reported.

The amended report of the Committee on Transportation, accepted by the American Railway Association, as information, May, 1911, and transmitted to your Committee X through Secretary Fritch, is as follows:

MEMORANDUM ON THE ESSENTIALS OF SIGNALING.

Incorporated in the Report of the Committee on Transportation of the American Railway Association, May, 1911.

The reports of various Committees of the Railway Signal Association and of the American Railway Engineering and Maintenance of Way Association on the subject of signaling have been submitted to this Committee, with the request that the essentials of signaling be outlined or defined for the future guidance of their Committees.

The subject has been carefully analyzed and considered. There are three signals that are essential in operation and therefore fundamental, viz.:

(1) Stop.
(2) Proceed with caution.
(3) Proceed.

The fundamental, "Proceed with caution," may be used with the same aspect to govern any cautionary movement, for example, when

(a) Next signal is "stop."
(b) Next signal is "proceed at low speed."
(c) Next signal is "proceed at medium speed."
(d) A train is in the block.
(e) There may be an obstruction ahead.

There are two additional indications which may be used where movements are to be made at a restricted speed, viz.:

(4) Proceed at low speed.
(5) Proceed at medium speed.

Where automatic block system rules are in effect, a special mark of some distinctive character should be applied at the stop signal.

The Committee therefore recommends:

SIGNAL FUNDAMENTALS.

(1) Stop.
(2) Proceed with caution.
(3) Proceed.

SUPPLEMENTARY INDICATIONS TO BE USED WHERE REQUIRED.

(4) Proceed at low speed.
(5) Proceed at medium speed.

Stop signals operated under automatic block system rules should be designated by some distinctive mark, to be determined by each road in accordance with local requirements.

RECOMMENDATIONS OF COMMITTEE X.

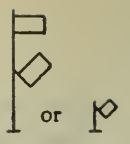
The simplest aspects for the three fundamental indications are:

1. Stop .....

2. Proceed with caution.....

3. Proceed .....

Having in view, and not desiring to depart from, the established practice of indicating diverging routes and incidentally low and medium speeds, your Committee recommends that the medium and low speed indications be given by an additional arm or arms. The simplest method (although incapable of expansion to provide additional aspects or even combinations of the fundamentals and supplementaries) is to use a second arm for both of these indications. The Committee on Transportation rules that the fundamental, "Proceed with caution," may be used to govern any cautionary movement. Therefore, for those roads which desire to operate under this plan and deem the five indications entirely sufficient, two additional aspects are necessary:

4. Proceed at low speed..... 

5. Proceed at medium speed.....

At interlocking plants which are also block stations it may be desirable, even on such roads, to give passenger trains caution signals for diverging movements, but not for entering occupied block sections; this would, with the system outlined above, require a separate signal beyond the interlocked switches. It may frequently also be desirable to display the fundamental, "Proceed with caution," on the medium-speed route, and to logically and consistently apply the fundamental aspects for "Proceed with caution" and "proceed" to those signals indicating medium speed and low speed, the 45-degree position should be used for caution and the vertical for proceed.

Again, as the Committee on Transportation merely makes optional the combination of various indications under caution and as several roads have found it desirable to differentiate between such indications, the Committee recommends for such roads a low arm as a low-speed arm and a middle arm where the indication of medium speed is desired.

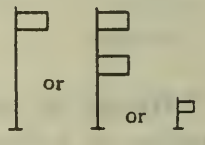
The Committee on Transportation states that "stop signals operated under automatic block system rules should be designated by some distinctive mark to be determined by each road in accordance with local requirements." The instructions to this Committee are to design a uniform system, which end is defeated if each road uses a different method of designating the automatic home signal. Therefore, the Committee recommends as follows:

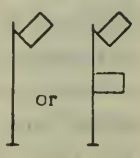
CONCLUSION No. 1.

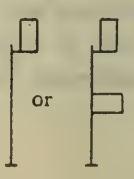
On roads desiring to operate with the three fundamentals and the two additional indications without expansion or combination of these indications, the following aspects may be used:

Scheme No. 1.

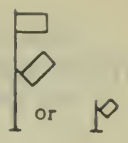
FUNDAMENTALS.

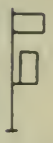
1. Stop..... 

2. Proceed with caution..... 

3. Proceed..... 

SUPPLEMENTARY INDICATIONS.

4. Proceed at low speed..... 

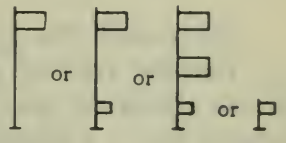
5. Proceed at medium speed..... 

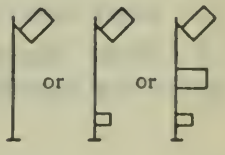
CONCLUSION No 2.

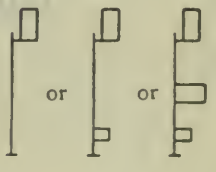
On those roads desiring combinations of the fundamentals and supplementary indications and different aspects for the various caution indications permissible under the ruling of the Committee on Transportation, the following aspects should be used:

Scheme No. 2.

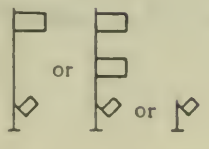
FUNDAMENTALS.

1. Stop..... 

2. Proceed, prepare to stop at next signal..... 

3. Proceed..... 

SUPPLEMENTARY INDICATIONS.

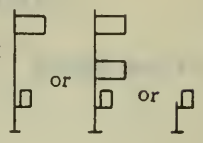
4. Proceed at low speed, prepare to stop..... 

5. Proceed at medium speed.....

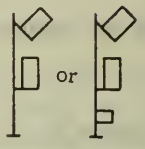
CONCLUSION No. 3.

When it is desired to indicate "Proceed at medium speed, prepare to stop at next signal," aspect..... should be used.

CONCLUSION No. 4.

When it is desired to indicate, "Proceed at low speed," aspect.....  should be used.

CONCLUSION No. 5.

When it is desired to indicate, "Proceed, prepare to pass next signal at medium speed," aspect.....  should be used.

CONCLUSION No. 6.

Where in manual block territory, it is desired to indicate "Proceed with caution, block occupied," aspect..... should be used.

CONCLUSION No. 7.

That the arms of automatic signals be pointed and the arms of other signals giving the stop indication have square ends; that, on roads using Scheme No. 1, a number plate be added on the automatic signal and, on roads using Scheme No. 2, a red marker light below and to the left of the active light be provided.

NOTE.—Messrs. Baker, Clausen, Scott, Stevens and Young do not approve the report on Subject No. 1.

Respectfully submitted,

COMMITTEE ON SIGNALS AND INTERLOCKING.

MINORITY REPORT OF COMMITEE X—AMERICAN RAILWAY ENGINEERING ASSOCIATION.

To the Members of the American Railway Engineering Association:

The undersigned believe that the indications provided by the American Railway Association are sufficient for the operation of any railroad and are all for which this Association should provide aspects.

We, therefore, recommend that the following indications specified by the Committee on Transportation of the American Railway Association and the aspects used to represent them be accepted and approved as recommended practice:

FUNDAMENTAL

1. Stop.....

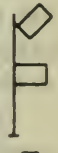
2. Proceed with caution.

3. Proceed.....

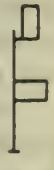
SUPPLEMENTAL

1. Stop.....

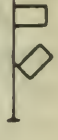
2. Proceed with caution.....



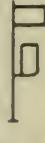
3. Proceed.....



4. Proceed at low speed....



5. Proceed at medium speed



(Stop signals operated under automatic block system rules shall be designated by a number plate.)

The specific objections to the additional indications and aspects provided by the Majority are the same as previously presented to this Association and are in accordance with the arguments presented before the Transportation Committee of the American Railway Association at Niagara Falls in June, 1910.

They are as follows:

1. It is impracticable to provide a separate signal for each of the conditions on a railroad requiring cautious running and to maintain the fine-haired distinctions necessary to their interpretation.

2. It is unnecessary, and, in fact, dangerous, to tell the engineman by fixed signal how he shall control his train at some point in advance.

3. Advance information so given is misleading and unreliable, as it is subject to change without notice, and therefore the engineman cannot safely use it. If he does so use it, it is done at the expense of safety.

4. The conditions of modern railway operation do not require trains to be run at full speed past Caution signals, and any time gained by this practice is at the expense of safety.

5. Each signal should indicate *Stop* or *Caution* or *Proceed,* and have no relation to signals in advance or in the rear.

6. Each signal should be observed in turn as the train comes to it, and not at some point in advance at the option of the engineman.

7. With signals properly located, it is time a train should be run with caution if it has reached a point so close to preceding trains or Stop signals in advance that a Caution signal is received.

8. No Proceed or Caution indication should "imply or assure clear track to a point in advance." Railway signaling devices and our methods of communication have not reached the perfection that will admit of this being done. We cannot know positively if the track is clear, and further, it may not stay clear. We are under a moral obligation not to give such misleading information.

9. The giving of information by signal indications about conditions in advance, whether it be regarding the next signal or the next station, or any other object or condition, is wrong practice, productive of laxity and a fruitful source of danger and accident.

10. It will be difficult, if not impossible, to maintain discipline and proper observance of the great variety of Caution indications proposed by the Majority, because of the fine distinctions involved.

A number of serious and fatal accidents in the past few years, wherein the engineman failed to properly observe the Caution signal, but fully intended to stop at the next signal, testify most conclusively to the correctness of our position in this matter.

Respectfully submitted,

H. S. BAKER,
W. B. SCOTT,
T. S. STEVENS,
J. C. YOUNG,
L. R. CLAUSEN.

REPORT OF COMMITTEE VII—ON WOODEN BRIDGES AND TRESTLES.

C. C. WENTWORTH, *Chairman;*
F. H. BAINBRIDGE.
F. E. BISSELL.
W. S. BOUTON.
R. D. COOMBS.
E. A. HADLEY.
W. F. STEFFENS, *Vice-Chairman;*
HANS IBSEN.
HENRY S. JACOBY.
J. A. LAHMER.
H. RETTINGHOUSE.
I. L. SIMMONS.

Committee.

To the Members of the American Railway Engineering Association:

COMMITTEE MEETINGS.

One meeting of the Committee was held in Chicago at the offices of the Association on October 2, 1911. Those in attendance were H. Ibsen, H. Rettinghouse, I. L. Simmons and C. C. Wentworth.

REVIEW OF THE REPORT OF 1911.

A pile record form was recommended and adopted. See Proceedings, Vol. 12, Part 1, page 307; also Manual, Edition of 1911, page 154.

Principles of practice for pile driving were recommended, and, after some amendment by the convention, adopted. See Proceedings, Vol. 12, Part 1, pp. 307 to 320, inclusive; also Manual, Edition of 1911, pp. 150 to 152, inclusive.

The remainder of the report on piles and pile driving was accepted as information, so also was the conclusion as to a means of protecting piling against marine borers by surrounding each pile with a vitrified clay pipe and filling the space between the pile and the pipe with sand. See Proceedings, Vol. 12, Part 1, page 322.

The work assigned by the Board of Direction for the year 1911 was as follows:

(1) Report on the formulas for use in determining the strength of sheet piling.

(2) Report on equipment required for pile driving.

(3) Collect information on special methods of driving sheet piles in cofferdams where conditions do not permit the use of ordinary equipment.

(4) Collect information on actual experience on the bearing power of piles and on the practical results of the use of formulas.

(5) Report on the use of guard rails for wooden bridges and trestles.

(6) Report on fire protection of wooden bridges and trestles.

In accordance with the general rules as to Committee reports given on page 14 of Bulletin 134, the following subjects were finally selected for consideration this year: Nos. 1, 4, 5 and 6 of the foregoing list. The Committee reports its progress thereon as follows:

(1) Sheet Piling—Prof. H. S. Jacoby, Chairman; and H. Ibsen, Sub-Committee:

This subject Committee VII did not think could be reported on this year, as an experimental investigation, which it was hoped Cornell University would make, could not be completed in time for report if undertaken; and it was thought that the result of these experiments would be of much service in making up its final report to the Association. The Committee has since been advised that Cornell could not undertake these experiments, but the Committee hopes that some other Institution may find it desirable that they be carried out by it.

The procedure suggested for these experiments was that a strong concrete open top box be made, across which at its middle a vertical plate diaphragm of tempered spring steel could be set; this diaphragm being held in place against horizontal motion at its top and bottom. On both sides of this diaphragm the box would be simultaneously filled with the material to be tested, as sand; thus, when the box is full, representing sheet piling driven in sand.

The sand was then to be removed from one side of the diaphragm, as would occur when a trench is excavated protected by sheet piling. After the diaphragm had assumed the curve due to the pressure of the sand its curved shape was to be accurately determined and a closely fitting template made to record its curvature.

In order to determine the amount and distribution of the sand pressure, the diaphragm would then be removed from the box and placed horizontally, supported at its ends at the same points it was supported by when vertical in the box. A number of metal strips should be provided, each long enough to reach across the diaphragm, but of varying thickness to make up any required weight, and of equal width. These would be piled at equal intervals on the diaphragm until the curve of flexure is again exactly reached by it which was given it by the sand and recorded by the template; bearing in mind that the tops of the successive piles of metal strips must be on a curve of some uniformity, which may be called the curve of load, without such irregular outline as that of a battlement, and carried over the supports on the line indicated by the curve approaching them. The total pressure, and the center of pressure, would thus be determined, it is thought, with considerable accuracy.

As a check, the flexure curve of the diaphragm already found could be plotted to a convenient scale, and successive differentials taken thereof up to and including the fourth. As the equation of this flexure curve is unknown, the differentiation would be done graphically, remembering that the first differentiation gives the curve of tangents to the flexure curve; the second the curve of moments; the third the curve of shear,

and the fourth the curve of load, which should agree with the curve of load determined by the first method—that of weights superimposed on the horizontal plate.

Other materials than sand need testing, such as a heavy semi-fluid mud, and ballast. In each case the angle of repose would be noted of the unretained material, and its weight per cubic foot.

In order to obtain definite conclusions the concrete box and steel diaphragm should be of rather large size; and to prevent the friction of the retained material on the sides of the box from affecting the result materially, narrower steel plates could be placed on each side of the main diaphragm, observations being taken on the main plate only.

The investigation could be extended to determine the pressure on abutments, which are generally filled against gradually on one side only, though this is not part of the work of this Committee. It seems probable that under such mode of filling, the total pressure would be greater, and its center lower, than in the case of sheet piling.

(4) Pile Formulas—F. E. Bissell, Chairman; F. H. Bainbridge, R. D. Coombs and W. F. Steffens, Sub-Committee:

A large number of requests for information were sent out, but the chief matter to be noted from the replies received was the very small number of roads keeping record of their pile driving in form for use in this investigation.

It seems to the Committee that while a pile driving formula should be based on theoretical considerations, there are so many modifying conditions to be allowed for that the result is a formula more or less empirical in its final make-up.

These modifying conditions can best be noted from actual experience in pile driving; and members are urged, for the advancement of the art, to keep record of the behavior of piles during driving and after loading. Especially is this record valuable in the case of test piles loaded to failure.

(5) Guard Rails—H. Ibsen, Chairman; Prof. H. S. Jacoby, I. L. Simmons and H. Rettinghouse, Sub-Committee:

A large amount of work was done on this subject, replies having been received from members and others representing a mileage of 119,314. These replies were tabulated and considered, but recommendations were not reached for presentation to the Association.

It seems that there are two types of guard rail in use; a guard rail being a member as defined on page 130 of the Manual, Edition of 1911. In one type the two rails are brought together at their ends at the middle of the track; in the other, two similar rails are not brought together at their ends, but remain parallel to the stock rail, and a third rail, also straight, is put in the middle of the track; all three rails in the latter case being deflected at their ends below base of rail.

(6) Fire Protection—I. L. Simmons, Chairman; F. H. Bainbridge, F. E. Bissell, H. Isben and J. A. Lahmer, Sub-Committee:

Replies to a circular letter of inquiry were received from members and others representing 110,214 miles of railway. Of this mileage 62 per

cent. when using fire protection adopted either full ballast decks, floors protected by a thin covering of ballast or other like material, or by sheet metal.

NEXT YEAR'S WORK.

The Committee recommends that the same subjects be assigned it for the year 1912 as were assigned for the year 1911, and given in full at the beginning of this report.

Respectfully submitted,

COMMITTEE ON WOODEN BRIDGES AND TRESTLES.

REPORT OF COMMITTEE XV—ON IRON AND STEEL STRUCTURES.

C. H. CARTLIDGE, *Chairman;*
J. A. BOHLAND.
CHARLES CHANDLER.
C. L. CRANDALL.
J. E. CRAWFORD.
J. E. GREINER.
J. M. JOHNSON.
C. N. MONSARRAT.
W. H. MOORE.
A. J. HIMES, *Vice-Chairman;*
ALBERT REICHMANN.
A. F. ROBINSON.
C. C. SCHNEIDER.
O. E. SELBY.
C. E. SMITH.
I. F. STERN.
F. E. TURNEAURE.
Committee.

To the Members of the American Railway Engineering Association:

Your Committee held two meetings during the year 1911—one at Niagara Falls on June 27 and the other at Chicago on October 24th.

We have to report as follows:

Subject No. 1—Investigation on Impact and Secondary Stresses: Appendix B contains a report from Prof. F. E. Turneaure, Chairman of Sub-Committee on Impact, giving an outline of the work done by the Committee during the past year.

Subject No. 2—Influence of Theory, Experiment and Experience on Bridge Design: It was unanimously decided by the Committee that it was unable to report adequately on this subject, and the request is therefore made that the subject be dropped.

Subject No. 3—Rules for Instruction and Guidance of Inspectors in Mills, Shop and Field: The Committee reports progress. The Chairman of the Sub-Committee has received discussion from two of the members of his Sub-Committee, and will probably be able to submit a paper giving the results of their findings during the next few months.

Subject No. 4—Design of Built-up Columns: The tender of the services of this Committee to collaborate with the Joint Committee of the American Society of Civil Engineers was made and very promptly accepted. Sufficient time has not yet elapsed to permit the organization of any actual work on this subject. The program proposed by the A. S. C. E. Committee is very elaborate and comprehensive and when carried out will immensely increase our knowledge of the subject. In order that this Committee do any practical work on this subject, it will be necessary to have funds. Your Committee understands, of course, that none of the funds of the Association are available for this purpose. We feel warranted, however, in recommending that individual roads be asked to contribute for the purpose of making these tests. This work

and that of the Impact Committee are original research work and it is hardly necessary for us to point out the ultimate value of the work done in the manner in which it has been done. It will probably be necessary in the near future to take cognizance of these experiments in our specifications for design, but the Committee does not recommend that any change be made at present, nor until further experiments on secondary stresses have been made, and if possible, considerable work on columns. The Committee will present later a more definite report of the probable amount of money needed for the first year's work. It is expected that this will be very small and that it can easily be raised.

Subject No. 5—Specifications for Erection of Steel Bridges: In Appendix A the Committee presents for the consideration of the Association a set of specifications, revised in accordance with the discussion at the last convention and with the written discussions from members and others received since the convention.

CONCLUSIONS.

The recommendations of the Committee are as follows:

(1) That the specifications for Bridge Erection be adopted and printed in the Manual.

(2) That the report of the Impact Committee be received as information.

(3) That no change be made at present in the specifications printed in the Manual.

Respectfully submitted,

COMMITTEE ON IRON AND STEEL STRUCTURES.

Appendix A.

SPECIFICATIONS FOR THE ERECTION OF RAILROAD BRIDGES.

Work to Be Done.

1. The Contractor shall erect, rivet and adjust all metal work in place complete, and perform all other work hereinafter specified.

Plant.

2. The Contractor shall provide all tools, machinery and appliances necessary for the expeditious handling of the work, including drift pins and fitting up bolts.

Falsework.

3. The method of erection and plans for falsework and erection equipment shall be subject to approval by the Engineer, but such approval shall not relieve the Contractor from any responsibility. Falsework will be built by *..... Falsework material of every character will be provided by the *.....

The temporary structure for use during erection and for maintaining the traffic shall be properly designed and substantially constructed for the loads which will come upon it. All bents shall be thoroughly secured against movement, both transversely and longitudinally. The bents shall be well secured against settling, and piles used wherever firm bottom cannot be obtained. Upon completion of the erection, the temporary structure, if the property of the Railway Company, shall be removed without unnecessary damage, and neatly piled near the site or loaded on cars, as may be directed. If the property of the Contractor, it shall be removed in a manner subject to the approval of the Engineer.

Falsework placed by the Railway Company under an old structure or for carrying traffic, may be used as far as practicable by the Contractor during erection, but it shall not be unnecessarily cut or wasted.

Conduct of Work.

4. The work shall be prosecuted with sufficient force, plant and equipment to expedite its completion to the utmost extent and in such a manner as to be at all times subordinate to the use of the tracks by the Railway Company, and so as not to interfere with the work of other contractors or to close or obstruct any thoroughfare by land or water, except under proper authority.

Reasonable reduction of speed will be allowed upon request of the Contractor.

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*Insert "Railway Company" or "Contractor," as the case may be.

Tracks shall not be cut nor shall trains be subjected to any stoppage except when specifically authorized by the Engineer.

The Contractor shall protect traffic and his work by flagman furnished by and at the expense of the Railway Company. The Contractor shall provide competent watchmen to guard the work and material against injury.

Engine Service.

5. If under the contract, work train or engine service is furnished the Contractor free of charge, such service shall consist only in unloading materials and in transferring the same from a convenient siding to the bridge site. Other engine service shall be paid for by the Contractor at the rate of $..... per day per engine, the time to include the time necessary for the engine to come from and return to its terminal. When engine service is desired the Contractor shall give the proper railway officials at least 24 hours' advance notice and the Railway Company will furnish the service as promptly as possible, consistent with railroad operations.

When derrick cars are used on main tracks, their movements shall be in charge of a train crew, and the expense of the crew and any engine service other than as noted above shall be charged to the Contractor.

Transportation.

6. When transportation of equipment, materials and men is furnished free over the Railway Company's line, it shall be subject to such conditions as may be stated in the contract.

Masonry.

7. The Railway Company will furnish all masonry to correct lines and elevations, and unless otherwise stated in the contract, will make all changes in old masonry without unnecessarily impeding the operations of the Contractor. The Railway Company's engineers will establish lines and elevations and assume responsibility therefor, but the Contractor shall compare the elevations, distances, etc., shown on plans, with the masonry as actually constructed as far as practicable, before he assembles the steel. In case of discrepancy, he shall immediately notify the Engineer.

Handling and Storing Materials.

8. Cars containing materials or plant shall be promptly unloaded upon delivery therefor, and in case of failure to do so the Contractor shall be liable for demurrage charges. Material shall be placed on skids above the ground, laid so as not to hold water, and stored and handled in such a manner as not to be injured or to interfere with railroad operations. The expense of repairing or replacing material damaged by rough handling shall be charged to the Contractor. The Contractor, while unloading and storing material, shall compare each piece with the shipping list and promptly report any shortage or injury discovered.

Maintenance of Traffic.

9. When traffic is to be maintained it will be carried on in such a manner as to interfere as little as practicable with the work of the Contractor.

Changes in the supporting structure or tracks required during erection shall be at all times under the direct control and supervision of the Railway Company.

Removal of Old Structure.

10. Unless otherwise specified, metal work in the old structure shall be dismantled without unnecessary damage and loaded on cars or neatly piled at a site immediately adjacent to the tracks, and at a convenient grade for future handling, as may be directed. When the structure is to be used elsewhere all parts will be matchmarked by the Railway Company; when the old bridge is composed of several spans the parts of each shall be kept separate.

Metal Work.

11. Material shall be handled without damage. Threads of all pins shall be protected by pilot and driving nuts while being driven in place.

Light drifting will be permitted in order to draw the parts together, but drifting for the purpose of matching unfair holes will not be permitted. Unfair holes shall be reamed or drilled.

Nuts on pins and on bolts remaining in the structure shall be effectively locked by checking the threads.

All splices and field connections shall be securely bolted prior to riveting. When the parts are required to carry traffic, important connections, such as attachments of stringers and floor beams, shall have at least fifty (50) per cent. of the holes filled with bolts and twenty-five (25) per cent. with drift pins. All tension splices shall be riveted up complete before blocking is removed. When not carrying traffic, at least thirty-three and one-third (33⅓) per cent. of the holes shall have bolts.

Rivets in splices of compression members shall not be driven until the members shall have been subjected to full dead load stresses. Rivets shall be driven tight. No recupping or calking will be permitted. The heads shall be full and uniform in size and free from fins, concentric and in full contact with the metal. Heads shall be painted immediately after acceptance.

Rivets shall be uniformly and thoroughly heated and no burnt rivets shall be driven. All defective rivets shall be promptly cut out and redriven. In removing rivets the surrounding metal shall not be injured; if necessary, the rivets shall be drilled out.

Misfits.

12. Correction of minor misfits and a reasonable amount of reaming shall be considered as a legitimate part of the erection.

Any error in shop work which prevents the proper assembling and fitting up of parts by the moderate use of drift pins, and a moderate amount

of reaming and slight chipping or cutting, shall be immediately reported to the Engineer and the work of correction done in the presence of the Engineer, who shall check the time expended.

The Contractor shall render an itemized bill for such work of correction for the approval of the Engineer.

Anchor Bolts.

13. Holes for all anchor bolts, except where bolts are built up with the masonry, shall be drilled by the Contractor after the metal is in place and the bolts shall be set in Portland cement grout.

Bed Plates.

14. Bed plates resting on masonry shall be set level and have a full even bearing over their entire surface; this shall be attained by either the use of Portland cement grout or mortar, or by tightly ramming in rust cement under the bed plates after blocking them accurately in position.

Decks.

15. The *..... will frame and place the permanent timber deck.

Painting.

16. The paint will be furnished by *..... and shall be of such color, quality and manufacture as may be specified.

Surfaces inaccessible after erection, such as bottoms of base plates, tops of stringers, etc., shall receive two coats of paint before assembling in place. After erection, the entire structure shall receive two coats of paint, allowing enough time between coats for the first coat to dry before applying the second. No paint shall be applied in wet or freezing weather, nor when the surface of the metal is damp. Painting shall be done in good and workmanlike manner, subject to strict inspection during progress and after completion, and in accordance with special instructions which shall be given by the Engineer. All metal shall be thoroughly cleaned of dirt, rust, loose scale, etc., before the paint is applied.

Clearing the Site.

17. The Contractor, after completion of the work of erection, shall remove all old material and debris resulting from his operations and place the premises in a neat condition.

Superintendence and Workmen.

18. During the entire progress of the work the Contractor shall have a competent superintendent in personal charge and shall employ only skilled and competent workmen. Instructions given by the Engineer to the superintendent shall be carried out the same as if given to the Contractor. If any of the Contractor's employés by unseemly or boisterous conduct, or by incompetency or dishonesty, show unfitness for employment on the work, they shall, upon instructions from the Engineer, be discharged

*Insert "Railway Company" or "Contractor," as the case may be.

from the work, nor thereafter be employed upon it without the Engineer's consent.

Inspection.

19. The work of erection shall at all times be subject to the inspection and acceptance of the Engineer.

Responsibility.

20. The Contractor shall assume all responsibility for loss or damage to his own work, materials or plant, due to any cause; also, for all loss or damage to the Railway Company's materials or property, and to other property adjacent to the railroad, due to causes within his reasonable control.

The Contractor shall assume all responsibility for injury to the workmen and the public, or to any individual; and in case of accident or suit he shall defend the suit in person and relieve the Railway Company from all costs and expenses, and pay any judgments that may be recovered thereon.

The Contractor shall comply with the laws and ordinances affecting the manner of doing work; shall take out all necessary permits and comply with their requirements, and shall take such precaution as may be necessary to protect life and property.

Insurance and Bond.

21. The Contractor shall carry such liability insurance as is necessary to protect himself and the Railway Company against loss or damage caused by injuries to his men, and shall furnish the Railway Company a bond in form and of a surety acceptable to the Railway Company, providing for the faithful performance of the work and all matters pertaining thereto, in such sum as shall be specified in the contract.

Engineer.

22. The term "Engineer," as used herein, shall be understood to mean the Chief Engineer of the Railway Company, or his accredited representative.

Clauses 20 and 21 to be eliminated; Clause 22 to be renumbered. See Index.

Appendix B.

SECONDARY STRESSES.

We herewith submit a brief report of progress relative to tests of secondary stresses, which were carried out during the past summer by your Sub-Committee on Impact and Secondary Stresses.

Through the assistance of the mechanician's shop at the University of Wisconsin, we were able to develop and manufacture a special form of extensometer for use in measuring secondary stresses. An important requirement of such an instrument is freedom from friction of all moving parts and, in general, a high degree of sensitiveness, combined with stability and strength of framework, convenience of adjustment and manipulation. An instrument was developed along the line of the extensometers used for impact tests, but to secure sensitiveness the principal bearings were made of knife edges, and instead of using a pencil for securing a continuous record, a ray of light is allowed to pass through a minute perforation in a disc at the end of the long lever, and a path of this ray of light is photographed on a moving slip of sensitized paper.

The apparatus proved satisfactory in practical operation, and the method of obtaining the record was found to be very good indeed. The sensitized paper was developed in the field so that results could quickly be obtained.

Four of these extensometers were made by the University of Wisconsin and were used by the Committee on its tests.

About three weeks were spent in the field and tests were made on the following bridges:

On the Chicago, Milwaukee & St. Paul Railway, a 160-ft. riveted span and a 176-ft. pin-connected span at Byron, Ill., a 104-ft. pony truss span at Rockton, Ill., in which eye-bars were used for the diagonal members, and a span of the same length at Brodhead, Wis., in which all members were riveted.

On the Chicago & North-Western Railway, a 182-ft. riveted truss, a 75-ft. deck-plate girder, and a through riveted lattice truss, all on the new Belt Line at Milwaukee.

At the present time preliminary results only are available, which are not in form for publication. It is expected that before the meeting in March it will be possible to present all important results, together with comparative results determined from a theoretical analysis.

In all of these tests the Railroad Company furnished a special train, and such other facilities in the way of mechanics as were needed; and your Sub-Committee desires here to express its great appreciation for the assistance thereby rendered.

The field work was carried out by Professors C. L. Crandall and F. E. Turneaure, members of the Sub-Committee, assisted by Messrs. W. L. Conwell and W. A. Axtell, of Cornell University, and Messrs. W. S. Kinne, O. L. Kowalke and J. B. Kommers, of the University of Wisconsin.

Respectfully submitted,

C. L. CRANDALL,
F. E. TURNEAURE,
Sub-Committee on Impact.

REPORT OF COMMITTEE XIV—ON YARDS AND TERMINALS.

C. H. SPENCER, *Chairman;*
HADLEY BALDWIN.
W. C. BARRETT.
M. S. BLAIKLOCK.
G. H. BURGESS.
A. E. CLIFT.
A. L. DAVIS.
H. T. DOUGLAS, JR.
A. C. EVERHAM.
D. B. JOHNSTON.
H. A. LANE.
E. B. TEMPLE, *Vice-Chairman;*
L. J. MCINTYRE.
B. H. MANN.
A. MONTZHEIMER.
W. L. SEDDON.
A. SWARTZ.
J. E. TAUSSIG.
E. E. R. TRATMAN.
W. L. WEBB.
J. G. WISHART.
Committee.

To the Members of the American Railway Engineering Association:

Your Committee on Yards and Terminals submits herewith its Twelfth Annual Report.

The Board of Direction has assigned the following subjects to your Committee:

(1) Report on typical situation plans of passenger stations, of both through and stub types, with critical analyses of working capacity, and include a review of the different methods of estimating their capacity.

(2) Report on developments in the handling of freight by mechanical means.

(3) Report on developments in the design and operation of hump yards.

(4) Report on typical situation plans for a division engine terminal.

(5) Report on methods of handling baggage, express and mail, at passenger terminals.

The Committee was also instructed to consider revision of Manual; if no changes were recommended, to make statement accordingly, and to make concise recommendations for next year's work.

The Committee held two meetings during the year, in addition to the meetings of the various Sub-Committees, as follows:

St. Louis, Mo., June 26 and 27; Washington, D. C., October 6 and 7.

A large amount of work has been done by all of the Sub-Committees on topics assigned to them.

REVISION OF MANUAL.

After careful consideration of the present Manual, the Committee has no recommendation for further changes at the present time.

(1) TYPICAL SITUATION PLANS OF PASSENGER STATIONS.

The Sub-Committee has accumulated a large amount of data with respect to existing terminals. The subject assigned, however, is so broad and important that it is desirable to continue work on it through another year. In view, therefore, of the expressed desire of the Board of Direction that the reports be limited as far as possible, it was decided to reserve report on this subject until next year.

(2) HANDLING OF FREIGHT BY MECHANICAL MEANS.

Considerable progress has been made at different points in the development of freight handling by mechanical means since the Committee's last report, and during the past year inspection was made of the new Missouri, Kansas & Texas Railway freight handling plant at Broadway Station, St. Louis, Mo., the Baltimore & Ohio Railroad telpher system at Pier No. 8, Locust Point, Baltimore, Md., the power conveyor system in one of the new warehouses of the Texas City Transportation Company, at Galveston, Texas, and of the electric truck system at Dock No. 6, Jersey City, N. J. As nearly all of these systems are practically new and sufficient time has not elapsed since installation to enable all points as to their utility to be definitely determined, both as to economy of operation and practical utility, full report on these systems is held over for future publication.

The attention of the Association is called to certain published articles noted below in relation to this subject:

1. Freight House at St. Louis, with Mechanical Freight-Handling Equipment; Engineering News, June 29; Railway Age Gazette, June 23; Railway and Engineering Review, November 11.

2. Electric Truck System at Dock No. 6, Jersey City, N. J.; Railway and Engineering Review, July 29.

3. Mechanical Handling of Freight (by S. B. Fowler); Proceedings of the American Society of Mechanical Engineers; Railway and Engineering Review, February 11.

4. Motor Trucks for Freight Transportation; Engineering News, June 22.

5. Freight Handling Installations at River Ports; Engineering News, May 4.

6. Mechanical Handling of Package Freight; Engineering News, May 11.

7. A Freight Station for the Use of Storage Battery Trucks; Engineering Record, January 28.

8. Electric Trucks for Handling Freight and Baggage; Engineering News, May 11, June 22, December 7.

9. Telfer System for Handling Baggage at an English Passenger Terminal Station; Engineering News, August 17.

10. Terminals, Yards and Mechanical Handling of Baggage at Stations; Bulletin of the International Railway Congress, November, 1911.

11. Cargo Transference at Steamship Terminals (H. McL. Harding); Proceedings of the Society of Naval Architects and Marine Engineers, 1911.

12. Terminals and Freight Piers at Boston; Engineering News, November 2, 1911.

13. Freight Piers and Freight Handling Machinery at Boston, Engineering News, November 9, 1911.

(3) DESIGN AND OPERATION OF HUMP YARDS.

Additional data on existing hump yards has been secured by Sub-Committee, and is held for future report.

(4) TYPICAL SITUATION PLANS FOR DIVISION ENGINE TERMINAL.

In treating this subject, the Committee understands its work to be the making of recommendations as to the best arrangement of facilities for the handling of locomotives at terminals rather than as to specifications for exact designs of the various structures involved, excepting as in a general way the characteristics of such structures seem to be more or less suited to the arrangement recommended.

It is also understood that the scope of the Committee's work does not include the consideration of shop or repair yard locations.

We submit herewith a typical plan or layout for an engine terminal whose characteristics permit of application equally well to larger or smaller demands practically without limit and without respect to whether the locomotives cared for are all freight or passenger, or in both kinds of service.

We have examined a number of plans of recently constructed engine terminals, and think we have adopted in our plan the best ideas of all, and that we have avoided the manifest errors of some at least of these plans. It must, of course, be recognized that in any case of actual construction, physical limitations as to space and shape of the ground site will impose more or less modification of the plan we recommend, but we think it will come more generally within the possibility of any given set of conditions than any other typical plan that could be suggested.

In locating an engine terminal, the facilities should be placed with reference to the yards and main line in the most advantageous position possible, that is, so that the distance between the engine terminal and the points where engines begin and end their service shall be a minimum, and so that reverse or conflicting movements shall be avoided as much as practicable.

The idea to be kept in mind is the most direct and convenient, that is, rapid and economical performance of those things required for an engine in its terminal in that sequence which answers all requirements in the order of their urgency. It appears to us that on the arrival of a locomotive at its terminal, the first imperative demand is likely to be

for water, and that this demand is likely to be the last when leaving the terminal for service, and for this reason our typical plan provides for the location of watering facilities accordingly.

After an incoming engine has been protected by receiving water, the next step appears logically to clean its fires or remove it entirely, according to need, and place the engine as quickly as possible in the engine house where the repairs necessary to prepare it for new service may be made, engine cleaned, etc. The cinder pit should be located as close as practicable to the engine house and permit at the same time of engines moving off cinder pit in normal direction, being switched direct to an outbound track without using or fouling turntable, as may often be desired.

It appears logical that the process of coaling should be reserved, if practicable, until just before the engine re-enters service in order that it may do so with a maximum supply of fuel, and also because the cleaning or removal of fire on cinder pit, as well as repairs of engine tank or other repairs, can be accomplished without that interference that might result from having tender filled with coal, and this reasoning dictates that the location of the coaling station should be primarily to serve the outbound tracks. Inasmuch, however, as it may often occur that incoming engines will require coal, the coaling station should be located as indicated on our typical plan, so that coal may also be taken by an engine on an inbound track.

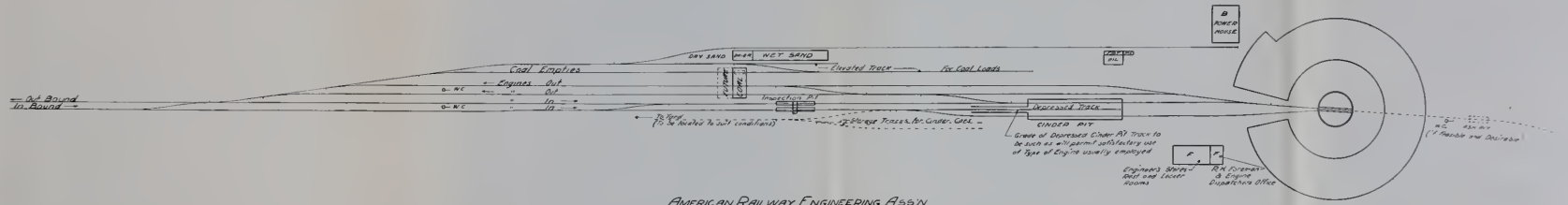
The trestle type of coal dock may be used if desired, if only two coaling tracks are required, and can be located between the inbound and outbound tracks in same relative position as shown in typical plan.

The most convenient and economical arrangement for storing and drying sand is at the coal station, where it may be handled by the same attendants. Sand should ordinarily be delivered to engines passing on the inbound tracks.

It will be observed that the arrangement of facilities permits of large increase in capacity of cinder pit, coaling station, etc., and in this connection the idea of having the coaling station at a busy terminal comprising two independent units makes a strong appeal for approval in view of the possibility of one of the hoisting plants suffering temporary disability from breakdown, or other cause.

The location of storehouse, oil house, enginemen's tool and locker rooms need not be arbitrarily prescribed, but should be as close as practicable to the engine house and the cinder pit. However, where any of these buildings are served by their own tracks, those tracks should be so located and connected as not to interfere with the uninterrupted free use of the engine tracks.

A system of ample lighting facilities is important, with lights distributed so as to avoid, as far as practicable, darkness or shadow where men are engaged in work upon engines.



AMERICAN RAILWAY ENGINEERING ASS'N
TYPICAL PLAN OF ENGINE TERMINAL
PROPOSED BY SUB COMMITTEE NO 2
YARDS & TERMINAL COMMITTEE

CONCLUSIONS.

(1) The engine terminal should be so located as to afford easy access to both Main Line and Yards, with the fewest possible reverse or conflicting movements.

(2) The facilities provided should be arranged to permit of the most direct and rapid handling of an engine in its terminal in the order of its needs.

The Committee recommends for next year's work a continuation of Subjects Nos. 1, 2 and 3, enumerated above.

Respectfully submitted,

COMMITTEE ON YARDS AND TERMINALS.

REPORT OF COMMITTEE II—ON BALLAST.

H. E. Hale, *Chairman;*
W. J. Bergen.
A. F. Blaess.
T. C. Burpee.
F. T. Darrow.
J. M. Egan.
T. W. Fatherson.
H. L. Gordon.
G. H. Harris.
J. M. Meade, *Vice-Chairman;*
C. C. Hill.
S. A. Jordan.
A. S. More.
J. V. Neubert.
S. B. Rice.
E. V. Smith.
F. J. Stimson.
S. N. Williams.

Committee.

To the Members of the American Railway Engineering Association:

Two meetings of the Committee were held in Chicago, one on July 27, and one on November 13, 1911.

Five meetings of Sub-Committees were held during the year, as follows: June 26, at Washington, D. C.; June 30, at St. Louis; July 27, at Chicago; October 7, at Chicago; November 1, at Washington, D. C.

REPORT ON THE PROPER DEPTH OF BALLAST TO INSURE UNIFORM DISTRIBUTION OF THE LOADS ON THE ROADBED.

REVIEW OF PREVIOUS REPORT.

The report of the Committee on the proper depth of ballast submitted during the year 1910 was in the form of a progress report, accompanied by a table showing the approved depth of ballast on various railroads, as printed in the Proceedings, Vol. 12, Part 1, page 345, but on account of lack of sufficient information on which to base definite recommendations, no action was taken on this subject by the Association.

DEFINITIONS.

Depth of Ballast.—The distance from the bottom of the tie to the top of the subgrade. (For definition of "subgrade," see Manual, 1911, page 16.)

HISTORICAL.

Various experiments and investigations have been made to determine the proper depth of ballast, and a list of some of the most important ones follows:

(A) Experiments by Railroad Director Schubert, in Germany, given

in Proceedings, American Railway Engineering and Maintenance of Way Association, Vol. 7 (1906), page 102.

(B) Report on the "Question of Strengthening the Track and Bridges, with a View to Increasing the Speed of Trains," made to the International Railway Congress by the Reporter for America, Mr. M. L. Byers, and later published in the Engineering News, of February 3, 1910.

(C) An article entitled "Gravel as Ballast," by Mr. C. Bräuning, translated from "Zeitschrift für Bauwesen," Vol. LIV, Berlin, 1904, being Appendix "C" (Bulletin 136, pp. 157-179).

(D) An article on "Ballast," by Mr. George W. Vaughan, Engineer Maintenance of Way, New York Central & Hudson River Railroad, printed in this report at Appendix "D" (Bulletin 136, pp. 180-190).

(E) Report of Pennsylvania Railroad General Manager's Committee appointed "To Determine by Experiment the Necessary Depth of Stone Ballast," dated March 5, 1911, being Appendix "B" (Bulletin 136, pp. 3-155).

(F) "A Study of the Stresses Existing in Track Superstructure and Rational Design Based Thereon," by Mr. O. E. Selby, Bridge Engineer, Cleveland, Cincinnati, Chicago & St. Louis Railway, published in Proceedings, American Railway Engineering and Maintenance of Way Association, Vol. 8, 1907, pp. 52-59.

ANALYTICAL.

Your Committee feels that very valuable information was given to the Association in the report of the Pennsylvania Railroad Committee on the necessary depth of stone ballast, published in Bulletin 136, through the kindness of Mr. W. C. Cushing, President of the American Railway Engineering Association, and Mr. L. R. Zollinger, Chairman of the Committee, appointed by the General Manager of the Pennsylvania Railroad.

The details of the test, which are very complete, are given in Appendix "D" of this report, and the conclusions, in so far as the proper depth of ballast which will insure uniform pressure on the subgrade, are as follows:

The tests made by the Pennsylvania Railroad at Altoona indicate that with approximately 320,000 to 440,000-lb. axle loads, or 75,000 lbs. each, passing over test ties on the test ballast, at five miles per hour, the subgrade practically reached a permanent settlement, and that where the ballast was materially less than 24 in., the settlement of the subgrade (loam) under the ballast was not uniform, but showed a greater settlement under the ties than between the ties.

These experiments further indicated that when stone ballast was placed 24 in. deep under the ties, the settlement of the subgrade (loam) under the ballast was practically uniform, and therefore the pressure must have been approximately uniform.

It was also found that a combination of stone and cinder ballast 24 in. deep under the ties (lower layer of cinders 18 in. to 14 in. deep, upper layer of stone 6 in. to 10 in. deep) gave nearly as good results, although

the deformation of the subgrade was greater than with 24 in. of stone ballast.

The result of this series of tests, which indicated that approximately 24 in. of stone ballast is required to produce a uniform pressure on the subgrade, with the ties spaced 24 in. to 25.5 in., center to center, agrees very closely with the formula given by Mr. Thos. H. Johnson, in the Proceedings of the American Railway Engineering and Maintenance of Way Association, Vol. 7 (1906), which was derived from the experiments of Director Schubert, namely, that with ties spaced 23 in. apart, center to center, stone ballast should be 22 2-3 in. deep to produce uniform pressure on the subgrade.

CONCLUSION.

With the data available, your Committee finds that with the ties (7 in. by 9 in. by 8½ ft.) spaced approximately 24 in. to 25.5 in., center to center, a depth of 24 in. of stone ballast is necessary to produce uniform pressure on the subgrade, and a combination of a lower layer of cinder ballast (18 in. to 14 in.) and an upper layer of stone ballast (6 in. to 10 in.), approximately 24 in. deep in the aggregate, with the same spacing of the ties will produce nearly the same results.

REPORT ON PHYSICAL TESTS OF STONE FOR BALLAST.

REVIEW OF PREVIOUS REPORTS.

The Physical Tests of Stone for Ballast adopted by the Association and described in Vol. 11 (1910), Part 2, pp. 910-914, were the first tests of this character adopted by the Association, and the question of revising the tests, if necessary. or adding other tests to those adopted, was again referred to the Ballast Committee for further investigation and consideration.

HISTORICAL.

Your Committee ascertained that the railroads as a rule had no uniform practice in making physical tests of stone for ballast. Some of the roads selected their stone for ballast by simply observing the character of the stone, and then ascertaining its durability and fitness for ballast by the actual results obtained in track. Some roads required a compression test in their specifications, but only one railroad was found to have used the physical tests made by the United States Government, previous to their adoption by the Association, as above referred to.

ANALYTICAL.

Your Committee does not recommend any changes in the physical tests already adopted, but feels that the tests would be more complete if the compression test were added.

With this in view, the question was taken up with the Department of Agriculture of the United States Government at Washington, D. C.,

*For amendment to Conclusion, see Index.

and they have agreed to add the compression test to those adopted by the Association, which were described in Vol. 11 (1910), Part 2, pp. 910-914, of the Association Proceedings.

The description of the compression test, which the Government will make, is as follows:

A cylinder two (2) in. in diameter and more than two (2) in. long is drilled from the specimen of stone to be tested, by means of a diamond core drill, and sawed to a length of two (2) in. by a band saw fed with emery. The specimen is finally faced off on each end by means of a power-driven grinding lap, on which water and emery are continuously fed.

The cylinder then has both ends embedded in plaster of paris, the bed being made as thin as possible and both ends being made parallel. The cylinder is next mounted on an Olsen test machine on a special bearing block between blotting papers, three thicknesses being placed at each end, between the cylinder and the steel-bearing faces of the machine. The load is then applied at a speed of 0.152 in. per minute, the machine being kept balanced during the application of the load.

Your Committee believes that with the physical tests of stone for Ballast, which the Association adopted, and the compression test above described, sufficient information will be given by which to compare the character of stone from the various quarries from which it is proposed to obtain ballast.

As a matter of information your Committee has, during the past year, requested a number of railroads to send samples of their stone ballast to the Government for test, and through the assistance and courtesy of these railroads we are enabled to present a tabulated statement of the results of these tests, and while this statement is not as complete as was desired, yet we feel it will be of considerable value in studying this question.

ADVANTAGES AND DISADVANTAGES.

The advantage of using approved physical tests of stone for ballast is to determine the character of the stone and its fitness for ballast without the expense of opening quarries and using the stone, before it is known whether it will be suitable for ballast or not, and without some method of determining this by physical tests, railroads will undoubtedly be put to considerable expense by opening quarries and applying stone ballast, which in some cases will have to be replaced with better ballast from other quarries.

CONCLUSIONS.

Your Committee recommends that in addition to the Physical Tests of Stone for Ballast, which have been adopted by the Association, that the "Compression Test," above described, be adopted and included in the Manual.

Your Committee also recommends that the following reference be made in the Manual to the description of the tests and the action necessary to have tests made:

"For the description of the physical tests of stone for ballast as recommended by the Association and full instructions as to how the samples should be obtained and shipped to the Government, see Proceedings of the American Railway Engineering and Maintenance of Way Association, Vol. 11, Part 2, pp. 910-914, and report of Ballast Committee of 1912. If blueprints of the machines used in making the tests are desired, they can be obtained from the Department of Agriculture, United States Government, Washington, D. C."

COMPLETE REVIEW OF GRAVEL BALLAST AND RECOMMENDED METHODS FOR GRADING THE DIFFERENT QUALITIES.

REVIEW OF PREVIOUS REPORT.

In the Proceedings of the American Railway Engineering and Maintenance of Way Association, of 1910, Vol. 11, pp. 909-932, a classification of gravel ballast was adopted by the Association, which depended on the amount of sand and dust found in the gravel, the size of the sand, and the size of the gravel, being determined in accordance with the definitions of "Sand and Gravel" given in the Manual, and this subject was again referred to the Ballast Committee for a complete review.

ANALYTICAL.

Your Committee, during the year, requested a number of railroads to test their gravel ballast and determine the percentage of sand, gravel (following the definitions of sand and gravel, given in the Manual), dust etc., in the ballast, and we present herewith a statement showing the percentages as found in ballast now in use, and a brief of the reports obtained from the railroads in regard to the use of these deposits of gravel for ballast is as follows:

The Santa Fe Railway reports that it is using the Chillicothe gravel almost entirely and finds it to be very satisfactory, giving good results on the roadbed, as it comes from the pit, using 12 in. under the ties.

The Chicago, Burlington & Quincy Railroad reports show gravel being taken from four different places, and put under the tracks as it is loaded from the pits, which makes excellent track, binds well and is easily worked.

The Chicago, Rock Island & Pacific Railway reports gravel taken from five different places, the best being from Benton, Ark., on their Southern lines, but not equal to the glacial gravel of Iowa and Illinois. The gravel was used on the track as it came from the pits, and not washed.

Twelve tests of pits on the Grand Rapids & Indiana Railroad are shown in the tabulated statement. The ballast is not washed, but is put in the track as it comes from the pit.

In the case of the Illinois Central Railroad, the tabulated statement shows tests from four different places, and the ballast from each is used

STATEMENT SHOWING PERCENTAGES OF SAND, CLAY, ETC., IN GRAVEL BALLAST

Name of Railway	Location of Gravel Pit	PERCENTAGES					Remarks
		Dust and Clay	Sand	Gravel	Rock	Voids	
C. B. & Q.....	Atchison, Kansas....	10.0	12.7	77.3	0.0	No Data	Per cent. by weight. Main track.
C. B. & Q.....	O'Neill, Neb.....	8.5	57.5	34.0	0.0	No Data	Per cent. by weight. Branch line.
C. B. & Q.....	Ballantine, Montana.	7.0	4.9	52.5	35.6	No Data	Per cent. by weight. Main line.
C. B. & Q.....	Peetz, Colorado.....	4.8	51.5	42.5	1.2	No Data	Per cent. by weight. Main line.
C. R. I. & P.....	Chillicothe, Illinois..	6.0	60.0	40.0	0.0	No Data	Per centage arrived at by volume.
C. R. I. & P.....	Grattinger, Iowa....	16.4	41.4	53.7	No Data	No Data	Percentage arrived at by volume.
C. R. I. & P.....	Benton, Arkansas....	23.3	20.8	79.2	No Data	No Data	
C. R. I. & P.....	On St. Louis Division	5.8	22.0	80.0	No Data	No Data	
C. R. I. & P.....	Nydia, Ark.....	16.3	11.8	90.9	No Data	No Data	
G. R. & I.....	Big Rapids, Michigan	6.0	32.0	78.0	No Data	No Data	Shown as good quality of ballast.
G. R. & I.....	Sand Lake, Michigan	18.0	44.0	63.0	No Data	No Data	Shown as fair quality of ballast.
G. R. & I.....	Leroy, Michigan.....	5.0	30.0	80.0	No Data	No Data	Shown as poor quality of ballast.
G. R. & I.....	Belmont Pit.....	0.5	15.0	91.0	No Data	No Data	Shown as good quality of ballast.
G. R. & I.....	M., G R. & I.....	0.0	40.0	75.0	No Data	No Data	Shown as fair quality of ballast.
G. R. & I.....	Paris Pit.....	15.0	40.0	70.0	No Data	No Data	Shown as poor quality of ballast.
G. R. & I.....	Grapo.....	11.0	36.0	72.0	No Data	No Data	Shown as poor quality of ballast.
G. R. & I.....	Reed City.....	5.0	40.0	72.0	No Data	No Data	Shown as poor quality of ballast.
G. R. & I.....	Tustin.....	8.0	42.0	72.0	No Data	No Data	Shown as poor quality of ballast.
G. R. & I.....	K. S. Tower Pit, Oden.....	13.0	60.0	48.0	No Data	No Data	Shown as poor quality of ballast.
G. R. & I.....	K. S. Tower Pit, T. C. Sect. 2.....	18.0	49.0	55.0	No Data	No Data	Shown as poor quality of ballast.
G. R. & I.....	K. S. Tower Pit, T. C. Sect. 3.....	15.0	56.0	50.0	No Data	No Data	Shown as poor quality of ballast.
G. R. & I.....	K. S. Tower Pit, T. C. Sect. 4.....	16.0	55.0	50.0	No Data	No Data	Shown as poor quality of ballast.

STATEMENT SHOWING PERCENTAGES OF SAND, CLAY, ETC., IN GRAVEL BALLAST.

Name of Railway	Location of Gravel Pit	PERCENTAGES					Remarks
		Dust and Clay	Sand	Gravel	Rock	Voids	
G. R. & I.....	Suttons Bay Pit.....	15.0	36.0	67.0	No Data	No Data	Shown as poor quality of ballast.
I. C.....	Forreston, Illinois....	4.8	17.2	72.0	6.0	20.0	
I. C.....	Riverton, Indiana...	7.9	23.5	68.6	0.0	13.4	
I. C.....	Gravel Switch, Kentucky.....	7.0	6.2	85.0	1.8	18.8	
I. C.....	Memphis, Tennessee.	3.3	17.8	77.7	1.2	17.3	
Mo. Pac.....	Fowler, Colorado....	2.0	65.0	33.0	0.0	No Data	Fair results.
Mo. Pac.....	Ft. Gibson, Oklahoma.....	5.0	4.0	94.0	0.006	No Data	Clay included in percentage of sand.
Mo. Pac.....	Bethel, Arkansas....	4.0	34.0	76.0	0.0	No Data	
N. Y. C. & H. R.	Beaver River.....	18.0	55.0	27.0	No Data	No Data	Sample No. 16.
N. Y. C. & H. R.	Yosts.....	5.0	20.0	75.0	No Data	No Data	Sample No. 17, first quality.
N. Y. C. & H. R.	Glenfield.....	18.0	57.0	25.0	No Data	No Data	Sample No. 19, coarse sand, very good but dusty.
N. Y. C. & H. R.	Todds.....	10.0	35.0	55.0	No Data	No Data	Sample No. 18.
N. Y. C. & H. R.	Fishers.....	8.0	27.0	65.0	No Data	No Data	Sample No. 21.

Note.—The sand and gravel in the ballast given in the above table was determined in accordance with the definition of sand and gravel in the Manual, edition of 1911.

in the track as it comes from the pits, except in the case of the Memphis gravel, which is taken from the bed of the Mississippi River and washed.

The Missouri Pacific Railway reports tests from three different places, and like the other roads the ballast was used on the track as it came from the pits.

It will be seen from the reports of the six different roads that no expense was incurred in washing or screening the gravel, which was used upon the tracks as it came from the pits, except in the case of the Illinois Central Railroad, for gravel secured at Memphis.

A report from the Chief Engineer of the Intercolonial Railroad of Canada states that he is of the impression that if they screened their gravel they would not get as good results as where they took the sand with a coarser material combined.

A report from the Engineering Department of the Canadian Pacific Railway states that they are ballasting with gravel taken direct from the pit, without any cost of treatment.

Your Committee further endeavored to determine the maximum amount of clay which would be permissible in good cementing ballast, and by reference to the data we have on this subject we find that most of the tests that have been made of gravel ballast give very meager information as to the amount of clay in cementing ballast, but from the best information we have at hand we are of the opinion that where the clay amounts to over 10 per cent. it would be quite objectionable.

Your Committee wishes to give a high endorsement of the report on "Gravel as Ballast," by Mr. C. Bräuning, which Mr. W. M. Dawley had translated from "Zeitschrift für Bauwesen," Vol. LIV, Berlin, 1904. We also present to the Association, under Appendix "A," a description and photographs of a gravel washing plant on the Richmond, Fredericksburg & Potomac Railroad, at Massaponax, midway between Richmond, Va., and Washington, D. C., which plant is under the charge of Mr. S. B. Rice, Engineer Maintenance of Way, to whom we are indebted for that report. The results obtained from this washed gravel ballast, as can be seen from this report, are far superior to the results obtained from the use of gravel for ballast without washing.

CONCLUSIONS.

Your Committee recommends further investigation of the amount of sand, dust and clay, permissible in good gravel ballast, since reports obtained this year from various railways, and attached hereto in a tabulated statement, indicate wide variations in the amount of these materials found in gravel ballast in actual use, yet reported as giving good results.

Respectfully submitted,

COMMITTEE ON BALLAST.

Appendix A.

GRAVEL WASHING PLANT OF THE RICHMOND, FREDERICKSBURG & POTOMAC AND WASHINGTON SOUTHERN RAILWAYS.

By. S. B. Rice, Engineer Maintenance of Way.

The latter part of July, 1907, or about the time the double tracking of the Richmond, Fredericksburg & Potomac Railroad and Washington Southern Railway had been completed, the officials were discussing the matter of using stone ballast to make the line first-class in every respect, it being a through trunk line between Richmond, Va., and Washington, D. C., with a traffic that is very heavy. We have an average of 24 through passenger and 10 local trains daily during the heavy season and an average of 20 through passenger and 10 local trains daily during the light season, the through trains consisting of from six to twelve cars and the local trains of from four to five cars. We have an average of 20 freight trains daily throughout the year. Weight of heaviest engine, 156,730 lbs. on drivers; total weight, 373,200 lbs.

About this time we had discovered a heavy deposit of very excellent gravel at Massaponax, Va., 57 miles from Richmond, midway between that point and Washington, and thought it possible that we could make a first-class road from this material. The gravel lies in a bed from ten to twenty feet in depth, about 800 ft. wide and 4,000 ft. in length. The pit we estimated to contain about 1,000,000 cu. yds. of serviceable material. The pit was opened on August 22, 1907.

The pit-run gravel from this pit was used on portions of our track and made an excellent track, but in long, dry seasons it was found to be very dusty, and in long wet spells we found that track became sloppy. In the latter part of 1907 we conceived the idea of washing and screening this material, as was done by the Lake Shore & Michigan Southern Railway at Roupel and Pleasant Lake. In July, 1908, W. D. Duke, Assistant to President; S. B. Rice, Engineer Maintenance of Way, and E. M. Hastings, Resident Engineer, made a trip to the Roupel plant with a view of looking into the advisability of duplicating this plant, also to have the opportunity of inspecting track that had been ballasted with washed gravel. Mr. Duke was so much pleased with the condition of the track and plant that he at once recommended the installation of the washing plant at Massaponax at the earliest possible time. The authority for this work was given in the latter part of July, 1908. Work was at once started on this plant and pushed as rapidly as possible to have it completed before bad weather set in. The first shipment of washed gravel was on November 20, 1908, starting at the Richmond end.

The plant consists of a large concrete hopper into which the pit-run gravel is dumped, from which it is carried by a pan conveyor having a speed of 30 ft. per minute, or 120 to 150 cu. yds. per hour, on an incline of 30 degrees, to the top of the trestle some 45 ft. high, where it is discharged into a steel-lined box, 6x3 ft. in plan and one foot deep in front, or at the chute. The water, discharged from a flat nozzle, one inch wide and 24 in. long, connected to a 6-in. discharge pipe, strikes the gravel as it falls into the box, washing it down over a steel-lined chute, six ft. wide and eight ft. long, with a slope of 3 in. to the foot.

It was found necessary, in order to more completely wash the gravel, to place a series of rods across the chute, making the gravel tumble over them, thereby retarding its progress and obtaining a more complete washing.

At the end of the chute there is a double screen placed at an angle of about 45 degrees with the chute. The screens are about 9 in. apart, and are of double-crimped tool steel wire. The first of No. 6 wire, one mesh to the inch; the second of No. 10 wire, two meshes to the inch. All gravel that does not pass these two screens falls into the ballast bin, which is 36 ft. long and 12 ft. wide and about 12 ft. deep. The lower six ft. of this bin is sloped toward the center, so that the gravel will fall by gravity through the openings in the bottom. (Fig. 4.)

All of the material which passes these two screens along with the water falls upon a second steel-lined chute which is eight ft. wide, nine ft. long, and a slope of two in. to the foot. From this chute the material is discharged against another screen, of double crimped tool steel wire No. 12, four meshes to the inch. This screen takes out practically everything larger than ⅛-in. in diameter. All material which does not pass this screen falls into the ballast bin also.

The material passing the screen is carried over another steel-lined chute about ten ft. wide and seven ft. long, where it is discharged as sand into a settling tank about 12x13 ft. and three ft. deep. On the side of the tank opposite this chute is the waste flume where the muddy water is carried off and discharged on the bed of gravel where the gravel had been previously excavated.

The settling tank is water-tight and is fitted at the bottom with two conical steel hoppers, six ft. in diameter at the top and ten in. in diameter at the base, five ft. deep. The bottoms of the steel cones are fitted with a steel cone plug which makes them nearly water-tight. The plugs or cones are operated from the top. The idea of having two of the conical hoppers was to grade the sand, the coarse sand settling in the first hopper and the fine sand in the farther one, there being a distinct difference in the two grades of sand. For this sand we have found ready sale, as it is of excellent quality for building purposes and concrete work, the finer sand making excellent engine sand.

The ballast bin is steel-lined throughout and has three openings at the bottom, fitted with 20x20 in. rack and pinion valves, spaced so as to empty into the center and two ends of the ballast car, giving a uniform

loading without necessitating the moving of car. The material is distributed in the ballast bin about equally over the three openings.

The water is brought from Massaponax Creek through a gravity canal, 900 ft. long (Fig. 1), to a concrete lined well, 7x5 ft. and 11 ft. deep; the bottom of the well being four ft. lower than the creek at the intake. This canal is a 20x20-in. open wood flume for 500 ft. where it runs into a 20x20-in. wood box, covered by some eight ft. of earth. This box is about 370 ft. long, where connection is made with an 18-in. terra cotta pipe, which runs under the engine foundation and pull-out track into the well, which is located close to the engine; this flume is always submerged. The pump is an Emerson pump No. 4 with a 6-in. suction, rated for a 5-in. discharge. The rated capacity is from 800 to 1,200 gallons per minute. To overcome friction it was fitted with a 6-in. discharge. The steam is furnished by a 90 H.P. return tubular boiler, which is under same roof as engine and pump. We also have a No. 5 pulling pump, rated at 350 gallons per minute, for the purpose of pumping water into a 25,000 gallon tank about 1,400 ft. distant, which is used by ballast and spotting engines. This tank is located on the pull-out track, just north of the coal bin.

At this point we have the office and bunk houses for both white and colored help. These bunk houses are separated. The Superintendent of the plant is on the ground at all times. Steam shovel and spotting engine crews are provided with both lodging and board.

The concrete hopper (Fig. 4), into which the pit gravel is dumped preparatory to washing, is 18 ft. above the foundation, 36 ft. long and 12 ft. wide inside, the outside walls are two ft. thick. The inside of the hopper slopes from the top all ways toward the center opening, which is 18x20 in., and provided with a steel sliding door which governs the feed on the conveyor. The slant sides of the hopper are six in. thick, reinforced with from ½ to 1½-in. iron rods, spaced 18 in. in centers and bent over into the two ft. outside walls. They are fastened together with ½-in. rods spaced about 12 in. apart. The track on the hopper is carried on 12x14 in. wood stringers, one of which is immediately over the outside wall, the other carried on 12x14-in. cross stringers, spaced six ft. c. to c., and imbedded in the outside walls. The track over the hopper is fitted with a bar screen, bars spaced 4½ in. apart, so as to prevent roots, stumps, boulders, or large lumps of clay from being carried to the washing plant.

The approach to the hopper (Fig. 1) is on a 2 per cent. grade ascending, which terminates at a point 150 ft. from the end of the hopper, thence by a 1 per cent. descending grade, which continues over the hopper, where it breaks into a 2.5 per cent. descending, then to a 5 per cent. descending grade for about 150 ft., then to an 18 per cent. ascending grade. At the junction of the 5 per cent. and 18 per cent. grades there is located a spring switch, the track leading away from the switch being on a descending grade to the pit level, the idea being to do most of the shifting by gravity. The loaded cars after being pushed up the 2 per cent. approach to the hopper are unloaded, dropped from the 5 per cent. grade by gravity, and up on the 18 per cent. grade, which gives them a kick back through

the spring switch and down to the pit level, where they are taken by the engine to be reloaded.

It is intended to cover the 112 miles of double track with washed gravel, thereby securing a dustless roadbed. In order to accomplish this we had new grades given, making a lift in track from 3 to 16 in., taking out some slight sags that were in tracks. Of course, where the track was lifted as much as 6 inches the old ballast could be worked under the ties, but at the other points the old sand and gravel ballast was thrown out to make roadbed. Ballast was loaded into the Rodgers drop bottom ballast cars and delivered in track, using a Rodgers plow for levelling down. This work was carried on by an extra force, renewing all ties that were not good for two years, regaging track and properly spacing ties ahead of new ballast. The renewal of ties and regaging was charged to maintenance; surfacing track was charged to reballasting. It required from 3,200 to 3,800 cu. yds. to the double track mile. The force employed at the pit consists of the following: One general foreman, one clerk, one shovel engineer, one craneman, one shovel fireman, four men at shovel, one engineer in charge of plant, one towerman who operates the machinery at top of plant, also looking after the screens, one foreman on hopper, one hopper and two helpers, one sand loader, one gravel loader and two droppers of cars. In addition to this there are three men on cars closing them up and calking and getting them ready for sand. Shifting track is generally done by section force and is, of course, charged to pit expense.

Since the starting of the washing plant there have been 371,877 cu. yds. of washed gravel shipped, of which 354,439 cubic yards were used for ballast and 17,438 cu. yds. for concrete and other purposes. From this total amount of gravel we have taken 78,232 cu. yds. of sand, most of which has been sold for building purposes. Of course, the hauling of this has been revenue to the Company. Cost per cubic yard of loading rough gravel, 8.95 cents; cost per cubic yard of washing gravel, 11.34 cents; cost per cubic yard for hauling, 11.11 cents; cost per cubic yard for placing in track, 26.15 cents; or a total cost of 57.55 cents per cubic yard of finished track. This cost includes hire of all engines, train crews, coal and supplies; rental of shovel, coal, supplies and repairs; one cent per cubic yard to cover cost of gravel in pit and 10 per cent. depreciation on plant and tracks; but no credit is taken in these figures for sand sold.

We have found by actual test that the washed gravel is nearly self-draining; it will not retain over 11½ per cent. of water, while the pit-run gravel will retain 55 per cent. It has been demonstrated that the washed gravel will withstand any amount of continued rain and not slop, while the pit-run would, causing rough track in continued wet spells. Aside from the better condition of track we estimate to add at least two years to life of the ties. It makes a dustless roadbed and reduces the cost of maintenance.

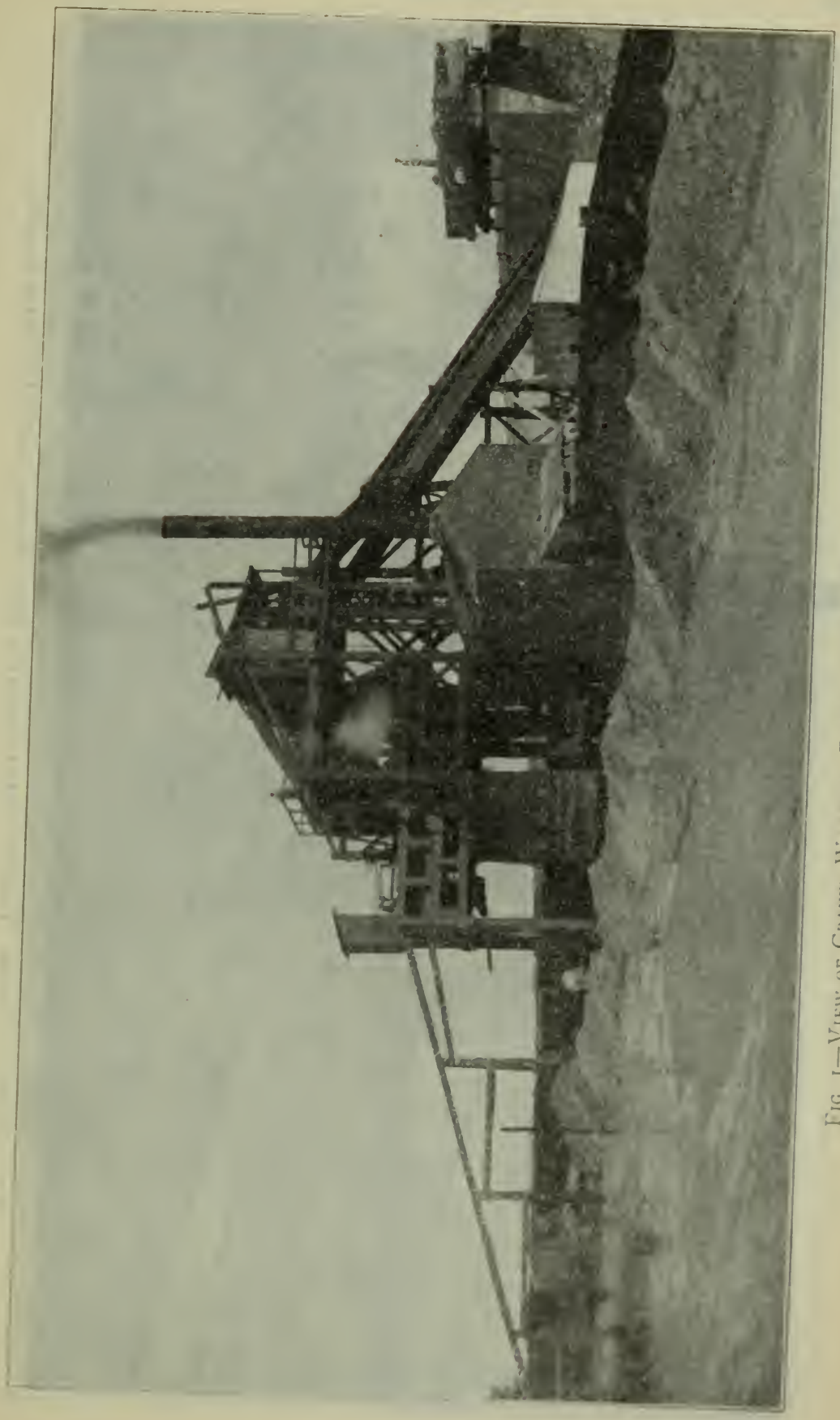


FIG. 1.—VIEW OF GRAVEL WASHING PLANT, WITH GRAVEL CAR AND HOPPER.

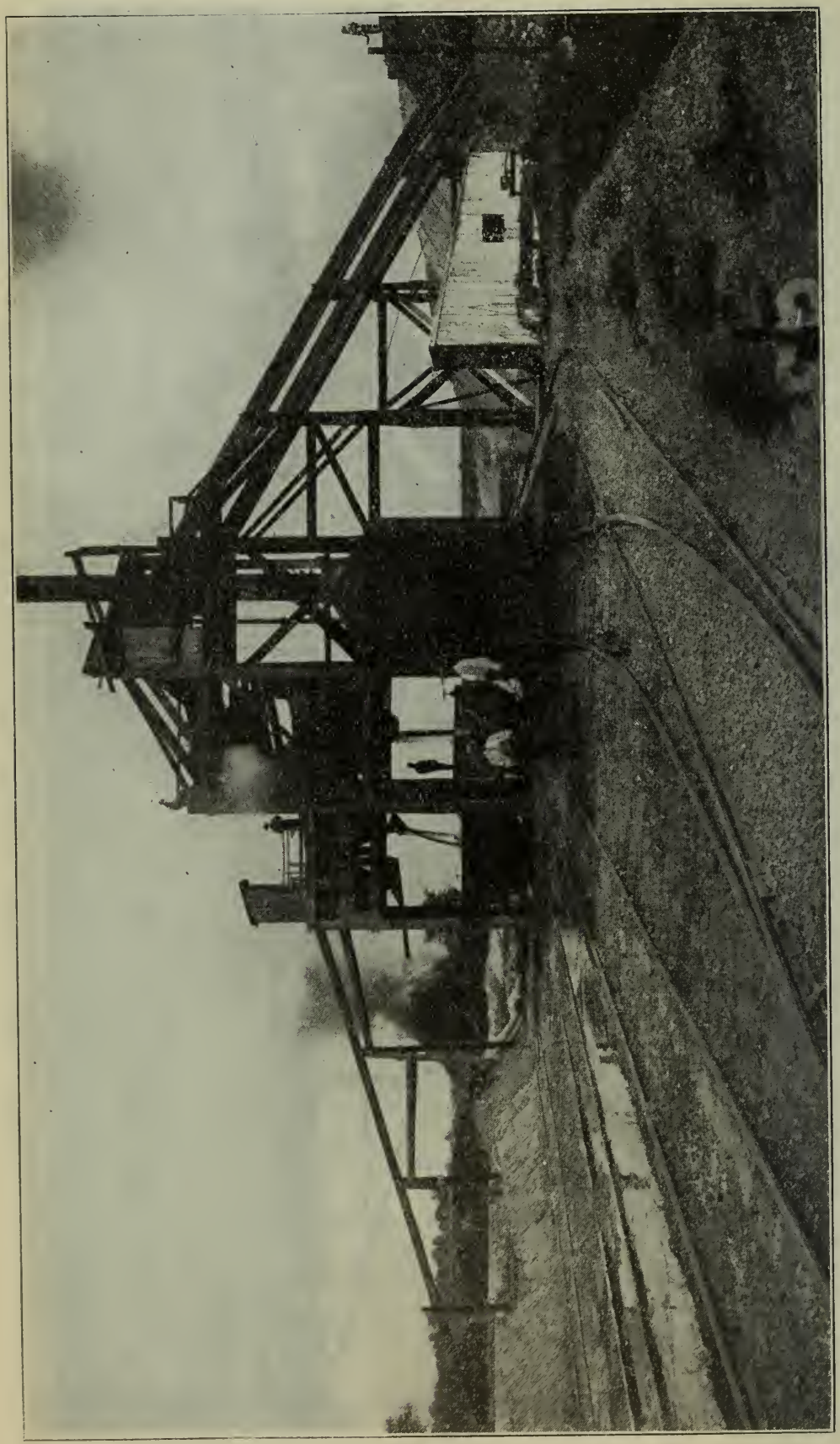


FIG. 2—VIEW OF GRAVEL WASHING PLANT, SHOWING BOTH BALLAST AND SAND BEING LOADED.

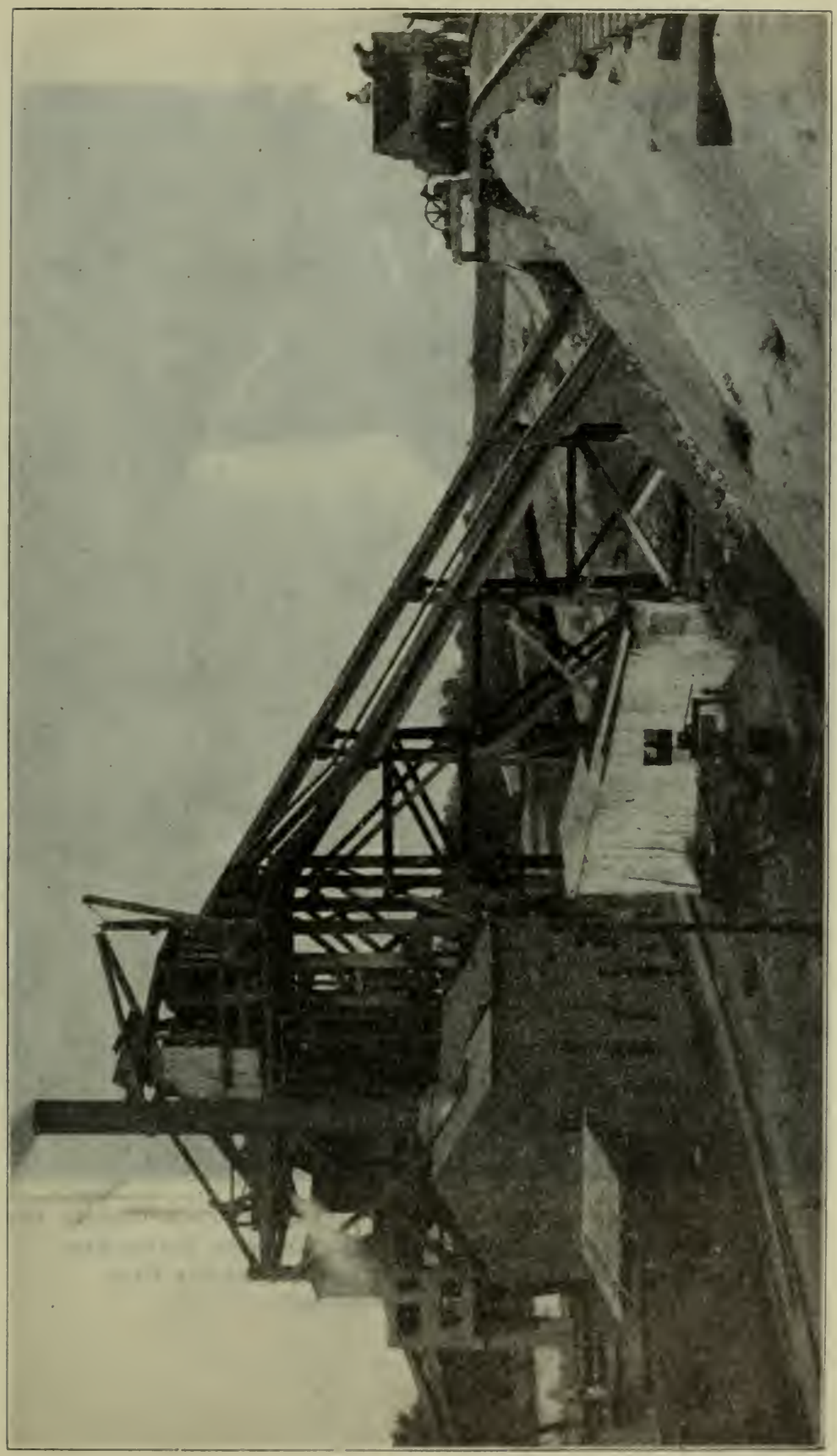


FIG. 3.—VIEW OF GRAVEL WASHING PLANT, SHOWING CARS BEING DUMPED INTO HOPPER.

FIG. 4—VIEW SHOWING WHERE GRAVEL IS EMPTIED FROM CARRIER AND WHERE WATER FIRST STRIKES IT, ALSO SHOWING ACTION THE BALLAST AND WATER TAKE IN PASSING OVER THE BARS INTO THE FIRST FLUME.

RESULTS OF GOVERNMENT TESTS ON STONE FOR BALLAST. RESULTS IN TRACK AND RAILWAY BALLAST SPECIFICATIONS

Ques. No.	SAMPLES: Furnished by	Kind of Stone	Location of Quarries	DETERMINATIONS BY GOVERNMENT: Weight Cubic foot, pounds	Water Absorbed Cubic foot, pounds	*Per Cent of Wear	†Hardness	‡Toughness	¶ Cementing Value	Crushing Strength	RESULTS IN TRACK	SPECIFICATIONS: Maximum Size in.	Minimum Size in.	GENERAL
3407	Baltimore & Ohio R. R.	Diorite (Trap)	Havre de Grace, Harford Co., Md.	103	0.35	2.5	18.5	23	8		In use 1½ years.			
3478-1	Baltimore & Ohio R. R.	Granite	Havre de Grace, Harford Co., Md.	168	0.25	3.0	18.6	10	15		In use 1½ years.			
3478-2	Baltimore & Ohio R. R.	Quartz, Hornblendschist	Havre de Grace, Harford Co., Md.	172	0.38	2.2	18.6	10	7		In use 1½ years.			
3694	Baltimore & Ohio R. R.	Gneissoid Granite	Havre de Grace, Harford Co., Md.	168	0.27	2.3	17.8	14	75	34,410	In use 1½ years; good so far	3	1	
3695	Baltimore & Ohio R. R.	Sericite Gneiss	Havre de Grace, Harford Co., Md.	168	0.26	2.6	19 0	9	13	20,060	In use 1½ years; good so far			
3696	Baltimore & Ohio R. R.	Gneissoid Granite	Havre de Grace, Harford Co., Md.	168	0.48	1.7	18.8	17	34	21,670	In use 1½ years; good so far			
3697	Baltimore & Ohio R. R.	Amphibolite	Havre de Grace, Harford Co., Md.	193	0.10	1.5	18.7	40	36	34,380	In use 1½ years; excellent so far			
3708	Baltimore & Ohio R. R.	Calcareous Sandstone	Columbus, Franklin Co., Ohio	168	0.98	4.3	15.5	9	81		Good service			
4188	Baltimore & Ohio R. R.	Trap	Savage, Md	190	0.15	1.4	18.8	37	Low		Excellent			
	Baltimore & Ohio R. R.	Siliceous Sandstone	McSpadden, Somerset Co., Pa.	168	0.58	2.5	18.2	11	10-25		Very good			Stone to be hard, durable, and of quality acceptable to Chief Eng. M. of W
3612	Baltimore & Ohio R. R.	Limestone	Bluestone, Fayette Co., Pa.	168	0.24	2.4	17.6	13	65		Good for limestone			Shall break in angular pieces when crushed and shall be thoroughly screened of all dust, dirt, and foreign matter.
3476	Baltimore & Ohio R. R.	Helderberg Limestone	North Baltimore, Seneca Co., Ohio	172	0.37	4.3	12.8	0	32		Fairly good			
3485	Baltimore & Ohio R. R.	Limestone	Martinsburg, Berkley Co., W. Va.	163	0.26	4.0	16.7	4	52		Poor			
4375	Baltimore & Ohio R. R.	Limestone	Sandusky, Erie Co., Ohio	165	1.46	4.4	10.4	8			Fairly good			
3586	Baltimore & Ohio R. R.	Calcareous Sandstone	Columbus, Franklin Co., Ohio	168	0.69	3.8	15.7	6	55		Good service			
3489	Baltimore & Ohio R. R.	Limestone	Engles, Jefferson Co., W. Va.	168	0.30	4.6	11.8	4	41		Good	Lime stone		
3634	Baltimore & Ohio R. R.	Dolomite	Millville, Jefferson Co., W. Va.	178	0.29	3.7	16.0	6	28		Poor			
3385	Baltimore & Ohio R. R.	Limestone	Kearneysville, Berkley Co., W. Va.	168	0.21	4.0	16.0	7	46		Good	3	½	
3382	Baltimore & Ohio R. R.	Limestone	Blaff, Rockingham Co., Va.	168	0.16	3.5	15.5	11	20		Not in use yet	Tr ap		
3383	Baltimore & Ohio R. R.	Dolomite	Brookewood, Augusta Co., Va.	175	0.66	3.1	16.5	16	23		In use only short while			
3384	Baltimore & Ohio R. R.	Limestone	Brookewood, Augusta Co., Va.	168	0.67	No test	15.4	5	23		In use only short while			
3385	Baltimore & Ohio R. R.	Limestone	Bluff, Rockingham Co., Va.	172	0.70	2.8	16 4	13	34		Not in use yet			
3671	Boston & Albany R. R.	Altered Diabase	Hampden Co., Mass	187	0.82	1.6	17.8	28	200	32,850	Considered excellent ballast			
3397	Carolina, Clinchfield & Ohio Ry.	Limestone	Quarry, Carter Co., Tenn. (Okolona)	168	0.34	4.4	16.0	9	64	22,750	In service only 2 years	2½	¾	
	Carolina, Clinchfield & Ohio Ry.		St. Paul, Russel Co., Va.	168	0.33	3.7	17.1	11			In service only 2 years			
	Carolina, Clinchfield & Ohio Ry.		Camp 8, McDowell Co., N. C.	168	0.28	3.5	18.8	15			In service only 2 years			
	Carolina, Clinchfield & Ohio Ry.		Cane Bottom, Yancey Co., N. C.	165	0.30	3 1	19.3	14			In service only 2 years			
	Central Railroad of New Jersey											2½	¾	
5514	Chicago & Alton R. R.											2	1	Thoroughly screened and free from dirt and foreign material.
5515	Chicago & Alton R. R.													
5523	Chicago & North-Western Ry.										In service only 2 years			
5524	Chicago & North-Western Ry.										In service only 2 years	2½	¾	
5525	Chicago & North-Western Ry.										In service only 2 years			
5526	Chicago & North-Western Ry.										In service only 2 years			
5395	Chicago, Rock Island & Gulf Ry.	Limestone	Stewartan, Jack Co., Texas	168	0.82	4.0	14.8	0	32		Used 8 years, does not pulverize; good	2	¾	
	Cleveland, Cincinnati, Chicago & St. Louis Ry.	Sandstone	Marion Quarries	153	2.66	4.2	17.2	8						
4399	Cleveland, Cincinnati, Chicago & St. Louis Ry.	Limestone	Property of Geo. B. Christian. Union Co., Ohio	165	1.31	6.1	13.2	10	53		Good service; wears round in 2 or 3 years.			
4421	Cleveland, Cincinnati, Chicago & St. Louis Ry.	Limestone	Weichheimer Co., Coles Co., Ill.	168	0.82	5.7	14.0	7	25	15,100	Good service; wears round in 2 or 3 years.			
4425	Cleveland, Cincinnati, Chicago & St. Louis Ry.	Limestone	Reliance Stone & Quarry Co., Madison Co., Ill.	168	1.42	4.2	14 2	6	40	17,300	Good service; wears round in 2 or 3 years.			
4655	Cleveland, Cincinnati, Chicago & St. Louis Ry.	Dolomite	Greensburg Limestone Co., Decatur Co., Ind.	175	0.74	4.8	14.0	6		17,960	Good service; wears round in 2 or 3 years.			
4657	Cleveland, Cincinnati, Chicago & St. Louis Ry.	Dolomitic Limestone	Hipskind Coal & Stone Co., Wabash Co., Ind.	168	0.87	3.9	14.5	6		18,790	Good service; wears round in 2 or 3 years.			
4680	Cleveland, Cincinnati, Chicago & St. Louis Ry.	Sandstone	Tunnel Hill, Johnson Co., Ill.	150	2.92	4.4	15.0	6		19,150	Good service; wears round in 2 or 3 years.			
4656	Cleveland, Cincinnati, Chicago & St. Louis Ry.	Argillaceous Limestone	Big Springs Quarry, Logan Co., Ohio	156	5.03	5.0	9.5	6		16,380	Good service; wears round in 2 or 3 years.			
4536	Cleveland, Cincinnati, Chicago & St. Louis Ry.	Limestone	St. Paul Quarries, Decatur Co., Ind.	168	1.58	6.1	14.3	5		18,400	Good service; wears round in 2 or 3 years.	2½	¾	
4659	Cleveland, Cincinnati, Chicago & St. Louis Ry.	Dolomitic Limestone	Greely Stone Co., Decatur Co., Ind.	168	1.14	4.8	14.7	6		20,510	Good service; wears round in 2 or 3 years.			
4695	Cleveland, Cincinnati, Chicago & St. Louis Ry.	Dolomite	Mills Bros., Clarke Co., Ohio	168	0.60	6.7	14.0	9		18,960	Good service; wears round in 2 or 3 years.			
	Cleveland, Cincinnati, Chicago & St. Louis Ry.	Dolomitic Limestone	Springfield Coal & Ice Co.	168	0.31	6.2	10.3	4		8,090	Good service; wears round in 2 or 3 years.			
	Cleveland, Cincinnati, Chicago & St. Louis Ry.	Dolomite	John Herzog & Sons, Hardin Co., Ohio	165	0.77		13.3	4		11,360	Good service; wears round in 2 or 3 years.			
4692	Cleveland, Cincinnati, Chicago & St. Louis Ry.	Dolomite	Moores Lime & Stone Co., Clarke Co., Ohio	168	1.54	6.8	11.3	4			Good service; wears round in 2 or 3 years.			
4690	Cleveland, Cincinnati, Chicago & St. Louis Ry.	Dolomite	Westport Stone Co., Decatur Co., Ind.	168	0.68	7.4	13 3	6		20,000	Good service; wears round in 2 or 3 years.			
4701	Cleveland, Cincinnati, Chicago & St. Louis Ry.	Dolomite	National St & Lime Co., Wyandotte Co., Ohio	165	1.34	5.0	8.8	3			Good service; wears round in 2 or 3 years.			
3393	Cleveland, Cincinnati, Chicago & St. Louis Ry.	Limestone	Ohio & Indiana Stone Co., Putnam Co., Ind.	168	0.59	3.2	15.8	11	40	16,000	Good service; wears round in 2 or 3 years.			
	Delaware, Lackawanna & Western R. R.											2½	¾	
5576	Erie R. R.													
5577	Erie R. R.											2½	½	
5578	Erie R. R.													
	Grand Trunk Ry.											2½	¾	
5549	Illinois Central R. R.	Limestone	Anna, Union Co., Ill.	168	0.42	3.3	14.3	9	16	19,510	Good; better than 5552			
5550	Illinois Central R. R.	Dolomite	Kankakee, Kankakee Co., Ill.	165	2.30	6.0	13.3	5	20	17,710	Good; better than 5552 and 5549	2½	½	
5552	Illinois Central R. R.	Dolomitic Limestone	Princeton, Caldwell Co., Ky.	168	1.88	6 1	14.1	12	10	23,860	Good; crushes a little in tamping			
5577	Lake Shore & Michigan Southern Ry.											2¾	½	
	Louisville & Nashville R. R.											2½	1	Free from dust, earth and trash.
5530	Missouri, Kansas & Texas Ry.											2½	½	Fitness judged by use in track.
5544	New York Central & Hudson River R. R.	Dolomite	Dutchess Co., N. Y. (Clinton Point Stone Co.)	175	0.33	2.3	16.8	23	33	29,050	Used for 20 years, hard; gives good service	2½	¾	
5576	New York Central & Hudson River R. R.	Argillaceous Limestone	Bellfonte Lime Co., Clinton Co., Pa.	168	0.00	4.3	15.3	8	34	18,710	Excellent results; pulverises a little			
5548	New York, New Haven & Hartford R. R.	Altered Diabase	Rutland Co., Vermont	184	0.06	2.0	17.2	15	111	16,500	Considered excellent ballast	3½	¾	
5568	Pennsylvania Lines, West.	Limestone	Marble Cliff, Franklin Co., Ohio	162	1.22	3.6		11	31		Fairly satisfactory; not as good as trap, softer and pulverises more			Limestone of approved quality. Graduated in size. Screened of all dirt and rubbish and stone smaller than 1 inch. Slabs passing 2½-inch ring and longer than 2 inch, must be broken by hand at place of loading. Lines East—Crushing Strength: Limestone, 10,000 lbs. per sq. in. Trap, 12,000 lbs. per sq. in.
5576	Pennsylvania Lines, West.	Limestone	Marble Cliff, Franklin Co., Ohio	162	2.14	2.2		7	31					
5579	Pennsylvania Lines, West.	Dolomite	Cook Co., Ill.	162	2.15	4.9	15.5	7	16		Same as 5505 and 5506	2½	1	
5534	Pennsylvania Lines, West.	Limestone	Kenneth Quarry, Cass Co., Ind.	163	0.40	5.1	13.8	5	30	20,350	Same as 5505 and 5506	Lines West		
5553	Pennsylvania Lines, West.	Dolomite	Dunkirk, Hardin Co., Ohio	165	2.78	3.5	15.1	16	25	26,200				
5554	Pennsylvania Lines, West.	Limestone	Sandusky, Erie Co., Ohio	168	1.05	3.9	17.3	10	17	21,850		3	1¼	
5555	Pennsylvania Lines, West.	Dolomite	Middlepoint, Van Wert Co., Ohio	172	0.76	5.3	10.3	13	16	25,200		Lines East		
5564	Pennsylvania Lines, West.	Limestone	Bloomville, Seneca Co., Ohio	168	1.00	3.0	12.5	6	22	20,250				
5557	Pennsylvania Lines, West.	Limestone	Walford, Lawrence Co., Pa.	163	0.25	4.9	16.5	7	26	27,500				
5558	Pennsylvania R. R.	Siliceous Limestone	Blairs Intersection, Westmorsland Co., Pa.	198	0.41	2.1	17.2	19	19	32,560				
5582	Pennsylvania R. R.	Altered Diabase	21 miles south of Birdsboro, Berks Co., Pa.	184	0.34	2.0	18.2	21	59	39,216	Considered excellent ballast			
	Philadelphia & Reading Ry.											2	1	
5544	Pittsburgh & Lake Erie R. R.	Limestone	Lawrence Co., Pa.	168	0.27	4.5	15.3	3	19		Used 10 years; very satisfactory results	2	¾	
5547	Pittsburgh & Lake Erie R. R.													
5418	Southern Ry.	Limestone	Crawford Co., Indiana, Milltown	168	0.65	3.6	12.7	8	90		Satisfactory; stand tamping well			
5420	Southern Ry.	Granite Gneiss	Rockliff, Polk Co., N. C.	172	0.33	0.0	17.8		16		Disintegrates easily; not good			
5449	Southern Ry.	Micro Granite	Stacey, Rockingham Co., N. C.	165	0.19	2.2	18 8	10	10		Very good			
5472	Southern Ry.	Ferruginous Sandstone	Gaithers Quarry, Prince William Co., Va.	182	2.90	4.0	16.3	7	50		Poor; breaks in tamping	2½	½	
5670	Southern Ry.	Limestone	Straw Plains, Jefferson Co., Tenn.	172	0.11	4.0		10	20	21,725	Good; will last 10 years; clean margin			
5668	Southern Ry.	Dolomite	Straw Plains, Jefferson Co., Tenn.	178	0.27	2.7		17	21	38,670	Good; will last 10 years, clean margin			
5674	Southern Ry.	Limestone	Straw Plains, Jefferson Co., Tenn.	172	0.41	4.5		8	15	28,335	Good; will last 10 years, clean margin			
5440	Virginia & Southwestern Ry.	Limestone	Sullivan Co., Tenn. (Bluff City)	168	0.40	5.8		5	18			3	¾	

*PER CENT OF WEAR—Resistance to wear in a special property of rock, and although it depends to a large extent upon both the hardness and the toughness of the rock, it is not an absolute function of these qualities. Figures shown in the table show the percentage by weight of dust or detritus worn off specimen in tests described on page 911, Part 2, Volume 11, Proceedings, American Railway Engineering and Maintenance of Way Association.

†HARDNESS—Result of tests in the table are interpreted as follows: Below 15, rock is called soft; 14 to 17, medium; above 17, hard.

¶ CEMENTING VALUE—The number given in the table represents the number of blows necessary to break the briquettes made from the sample of stone, and the test is described on page 913, Part 2, Volume 11, Proceedings, American Railway Engineering and Maintenance of Way Association. The greater the number of blows required to break the briquette, the higher the cementing quality of the rock.

‡TOUGHNESS—Figures shown in the table are interpreted so that those rocks which run below 13 are called low; from 13 to 19 medium, and above 19 high.

Appendix B.

(Bulletin 136.)

EXPERIMENT TO DETERMINE THE NECESSARY DEPTH OF STONE BALLAST.

To the Members of the American Railway Engineering Association:

In the Proceedings of the Association, Vol. 7 (1906), page 102, the writer called attention to the experiments of Railroad Director Schubert of Germany to determine the depth of ballast necessary to distribute the superimposed loads arising from the traffic to the best advantage over the roadbed, and these experiments of Director Schubert have inspired the Pennsylvania Railroad Company to supplement the data obtained at that time by a series of experiments, or tests, on a larger scale and more in accordance with the conditions to be met with in the United States.

Through the kindness of the Pennsylvania Railroad Company and Mr. L. R. Zollinger, Engineer of Maintenance of Way, the Chairman of the Committee appointed to conduct the tests, the writer is enabled to present the information in full to the members of our Association.

These tests are the most extensive of the kind ever conducted in this country, and will be found of great interest and value to railway engineers.

It is worthy of note how closely the depth of stone ballast, determined by these experiments as necessary for the best distribution of the superimposed loads, 24 in., agrees with the depth for the same material as given by Mr. Thos. H. Johnson's formula, which he derived from Director Schubert's experiments, viz., 22⅔ in.

W. C. Cushing,
Chief Engineer Maintenance of Way,
Pennsylvania Lines West of Pittsburg.

June 5, 1911.

THE PENNSYLVANIA RAILROAD COMPANY.

REPORT OF THE GENERAL MANAGER'S COMMITTEE APPOINTED TO DETERMINE, BY EXPERIMENT, THE NECESSARY DEPTH OF STONE BALLAST.

COMMITTEE.
L. R. Zollinger, *Chairman;*
E. D. Nelson,
Allen B. Cuthbert,
G. W. Snyder.

Philadelphia, March 5, 1911.

Mr. S. C. Long,
General Manager.

Dear Sir:—Your Committee, appointed to determine, by experiments, the proper depth of ballast under track necessary to equally distribute the pressure, due to moving loads on the surface of the underlying material, submits the following report:

During the years 1887 to 1890, inclusive, Railroad Director Schubert of Germany conducted a series of experiments to demonstrate, "Which ballast material affords the best distribution of force upon the subgrade or roadbed." These experiments were conducted by filling boxes with layers of different kinds of ballast and other material upon which a section of a tie was laid. This tie was then tamped in the ordinary way and subjected, by means of an eccentric, to a load which was alternately imposed upon and lifted from the tie—thus imitating the process of passing a loaded wheel over the track. After repeated tampings and applications of the load the ends of the box were removed and the conditions beneath the tie investigated. One of the conclusions drawn from the experiment was, as the depth of stone ballast under the tie increased, that the distribution of pressure on the underlying material became more uniform.

The data obtained by Mr. Schubert were very instructive, yet your Committee felt that more valuable data could be obtained from a series of experiments if made in a manner approaching more nearly actual track conditions.

Accordingly, at South Altoona Foundries, a piece of single track was constructed, under which were placed three strong boxes open at the top and having removable ends, each box sufficiently large to contain two standard ties spaced the standard distance apart; the boxes were filled with various kinds of ballast and roadbed material.

A heavily loaded truck was designed to run back and forth on the track so that the effect of its load acting through the ties upon the ballast and roadbed could be studied by the removal of the ends of the boxes, when measurements and photographs could be taken. The general arrangement of the plant is shown by the photographs, Figs. 1, 2, 3. The track was 109 ft. in length, built of new P. R. R. standard 85-lb. rail,

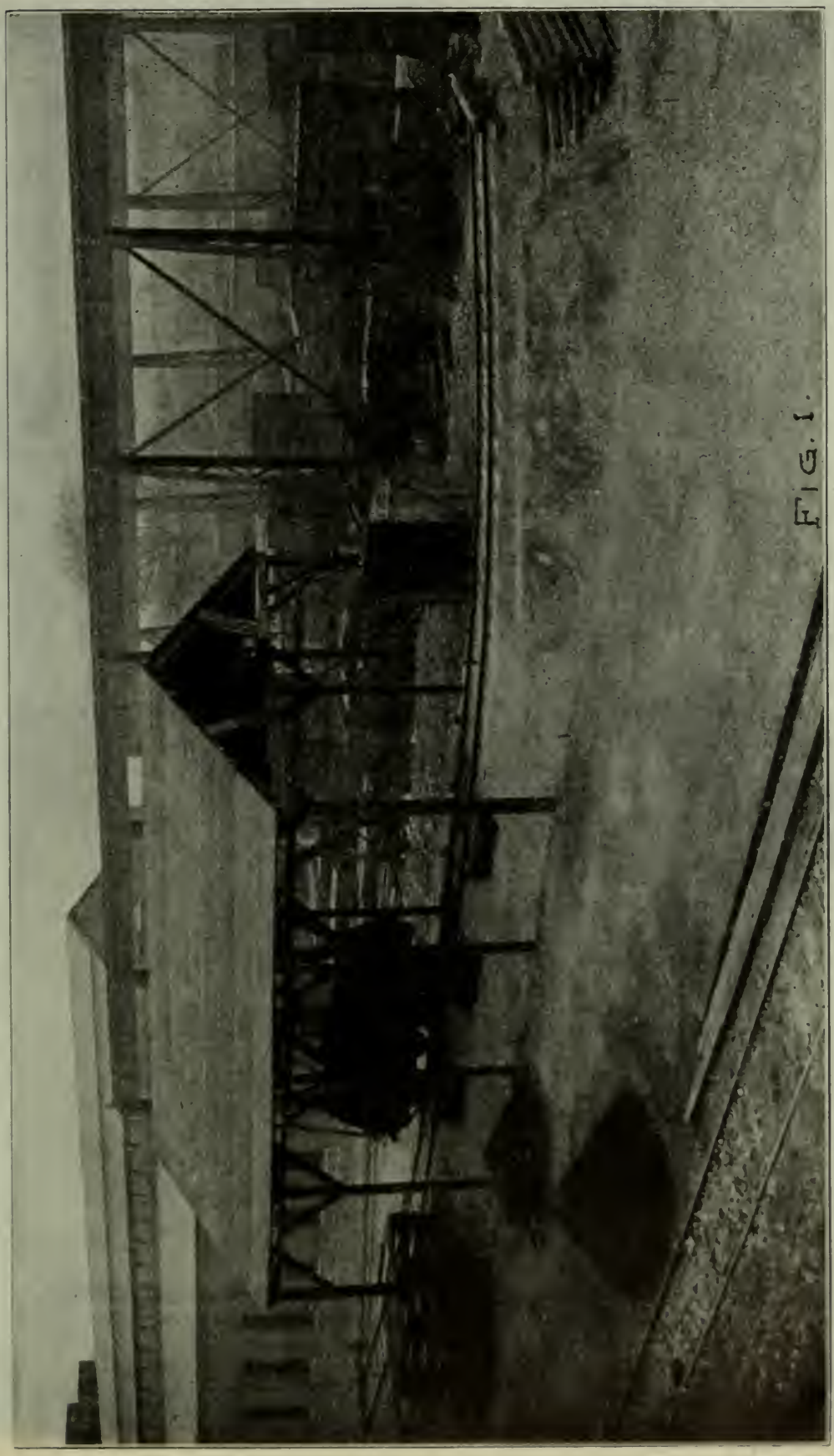
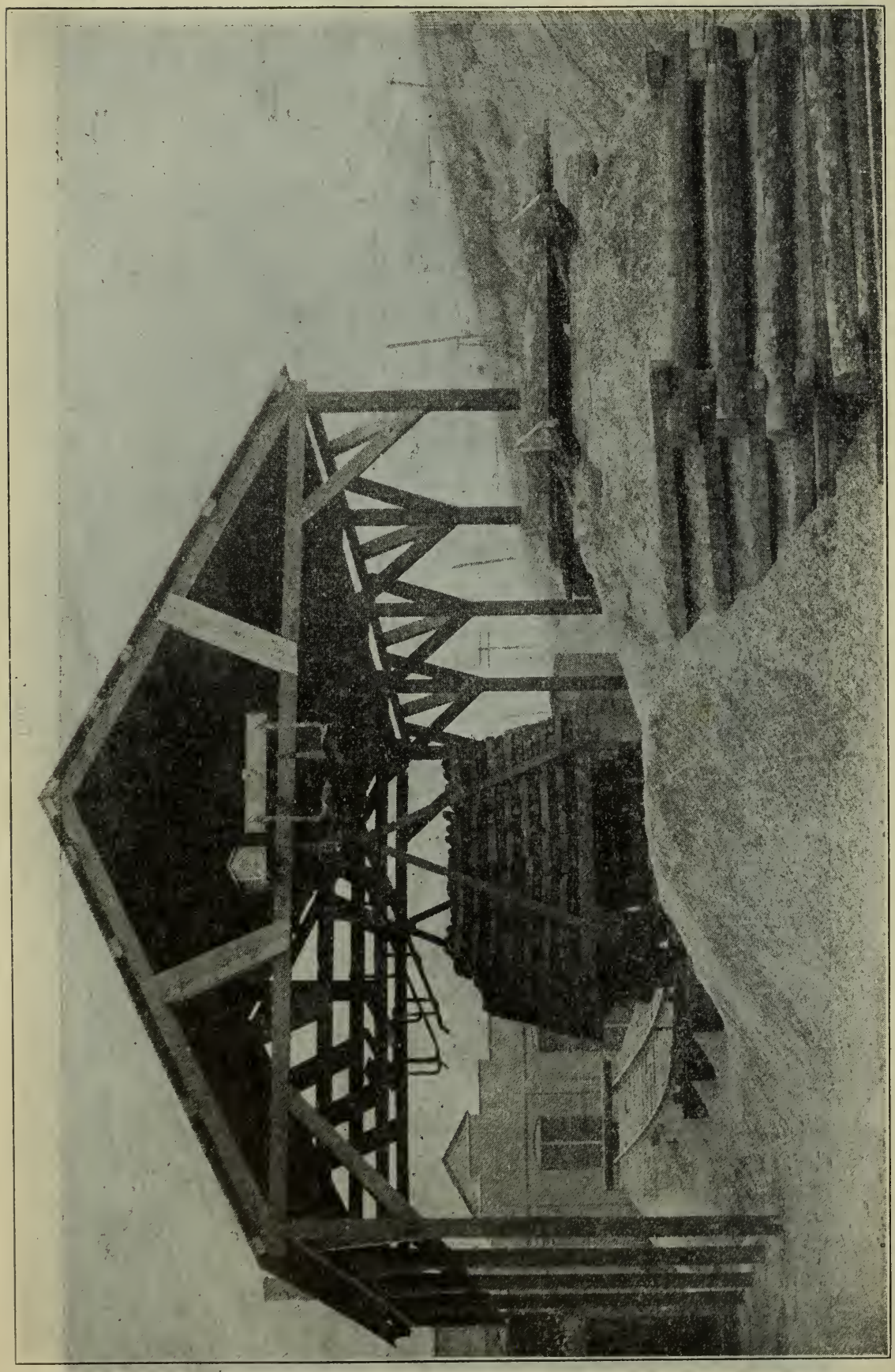


FIG. 1.



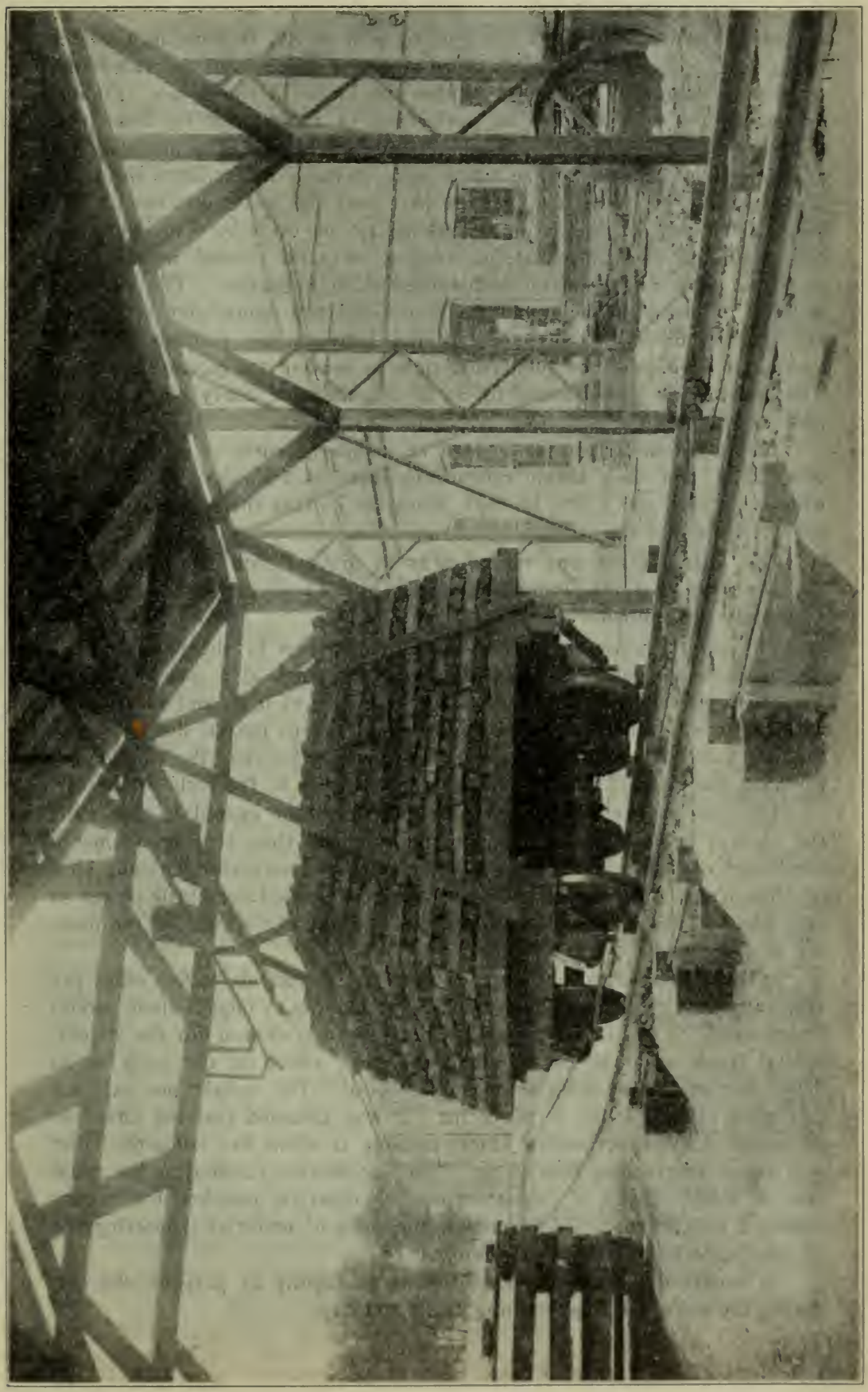


FIG. 3.

spiked to standard white oak ties 7 in. by 9 in. by 8½ ft. long, no tieplates being used. The rail fastenings were standard spikes, and the rail joints were so arranged as not to fall within the limits of the boxes. Eighty-five-pound rail was selected in preference to 100-lb. rail in order that the track might be sufficiently flexible to subject the ties to as much weight as possible. The ends of the track were elevated to facilitate the stopping and starting of the car, but the part over the boxes was level. The boxes were built of yellow pine planking 4½ in. thick by 8 in. wide and had floors of the same material resting on sand several inches deep, which, in turn, rested on an undisturbed shale formation. The site was selected to provide a solid bottom to prevent any appreciable settlement taking place in the boxes. The joints between the planks were not tongued and grooved nor sufficiently tight to prevent the passage of water. The boxes were strengthened by an arrangement of heavy posts and tie rods, as the photographs show.

The boxes under the track were 12 ft. apart, center to center. They were alike, and their inside dimensions were as follows: 4 ft. 8½ in. wide, 9 ft. long and 3 ft. 4 in. high, being set so that their tops were 2 in. below the base of the rail.

The testing plant was roofed over to prevent rain from falling on the boxes so that the amount of water applied to the boxes could be accurately determined.

The car or truck having two axles (as shown by the photographs) was designed to run back and forth upon the track at a speed of about five miles per hour. The car had a wheel base of 9 ft. and was loaded with pig iron, so that the gross weight amounted to 150,000 lbs., or 75,000 lbs. per axle. There was no spring intervention between the weight and the axle, the journal boxes being fastened directly to the body of the car.

The car was kept moving by an electric motor geared to one axle, the current being supplied through an overhead shoe bearing against a conductor. At the elevated ends of the track a device automatically shut off the current and reversed the motor; the car needed very little power or attention to keep it in motion. A counter on the car registered the number of trips made.

It being impracticable to run the car faster than about five miles per hour, at which speed any effect upon the track, due to impact alone, would be negligible, a weight of 75,000 lbs. per axle was chosen for the experimental truck, so as to obtain about the same effect on the track as an "H8b" locomotive running at the usual speed. The weight per axle for this class of locomotive is 58,100 lbs. It was assumed that the effect on the track of the experimental truck, running at about five miles per hour, was about as great as that of an "H8b" locomotive running at the usual rate of speed. Even if the assumption is open to question, the results obtained with the use of different combinations of material supporting the tie can be, at least, considered comparative.

In order to conduct the experiments as rapidly as possible, the car, during the tests, was kept running night and day.

The running back and forth of the loaded truck over the track resulted in a settlement of the ballast and roadbed materials contained in the boxes. After a settlement was noticed, aggregating about an inch, the car was stopped and the track raised to its original elevation and surfaced by tamping the stone ballast with tamping picks according to the usual service methods, the proper elevation and levels of the track being determined by the use of a "Y" level. The truck was then started and the above operation repeated from time to time, additional ballast being added, when necessary, to supply the loss due to tamping and settlement.

In filling the boxes in each test, the loam, clay, engine cinder or other material, except the stone ballast, was compacted by a rammer, care being taken to ram each box and each kind of material as nearly alike as possible.

The truck was kept running and the accumulated results of settlement were noted until the decrease in the daily settlement was so marked that it was considered time to close the test, when the boxes were opened and at each end three vertical sections parallel with the rail were cut in the ballast and roadbed materials; the first was taken at the end of the tie; the second half-way between the tie and the end of the rail; and the third beneath the rail. Each section was photographed, also carefully measured by the use of the "Y" level, to show the curve or line between the ballast and the various materials with which each box was filled. In addition, measurements were made in the same manner of vertical cross-sections at right angles to the track; first, under the middle of the north tie; second, under the middle of the south tie; and third, midway between the two ties. The data thus obtained were plotted for each box, in each test, and appear in the appendix.

In addition to this, other data were collected showing the amount of daily settlement of the rail over each box; also, the amount the track was raised each time it was tamped. The total number of trips of the car was recorded, as well as all other data that would influence the results obtained.

In order to simulate natural conditions as to rainfall, water in known quantities was sprinkled over each box for the purpose of wetting the ballast and roadbed materials, to induce settlement and possibly to produce pumping track, but the latter never developed. A careful record was kept showing when the water was applied and of the amount in its equivalent in inches of rainfall.

While the various tests were being conducted the ties adjacent to and between the boxes were kept slightly loose, as far as tamping was concerned, in order that the full weight of the car, in passing, would come upon the two ties in each of the three boxes.

A series of five tests has been completed; the first one beginning on September 2, 1908, and the last one ending on August 2, 1910.

The attached diagram, Fig. 4, shows the relative position of the various kinds of material used in each box and for each of the five tests.

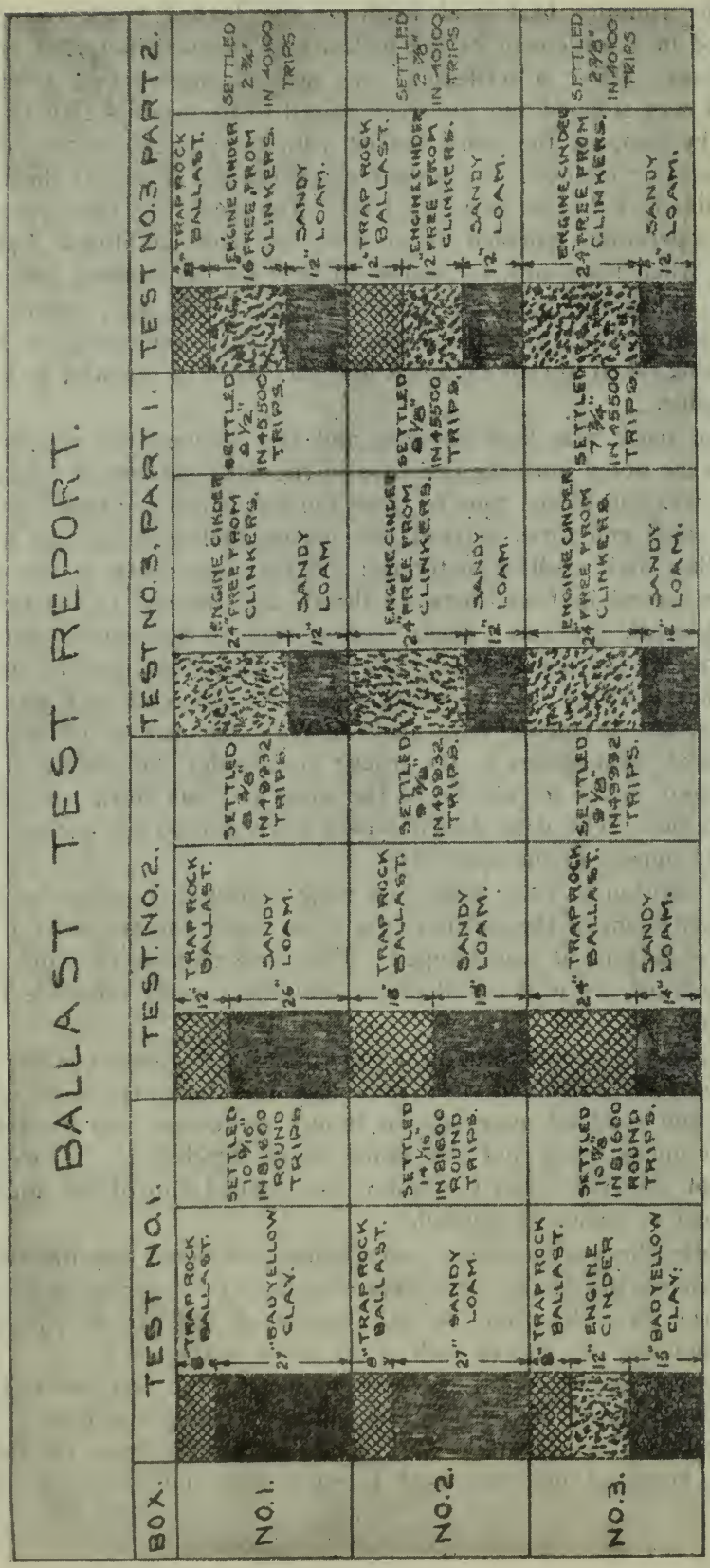

BALLAST TEST REPORT.
BOX.
TEST NO.1.
TEST NO.2.
TEST NO.3, PART 1.
TEST NO.3 PART 2.
NO.1.
NO.2.
NO.3.
8" TRAP ROCK BALLAST.
27" BAY YELLOW CLAY.
SETTLED 10 9/16" IN 81600 ROUND TRIPS.
12" TRAP ROCK BALLAST.
26" SANDY LOAM.
SETTLED 8 3/8" IN 49932 TRIPS.
ENGINE CINDER 24" FREE FROM CLINKERS.
12" SANDY LOAM.
SETTLED 9 1/2" IN 45500 TRIPS.
2" TRAP ROCK BALLAST.
ENGINE CINDER 16" FREE FROM CLINKERS.
12" SANDY LOAM.
SETTLED 2 3/4" IN 40100 TRIPS.
8" TRAP ROCK BALLAST.
27" SANDY LOAM.
SETTLED 14 1/16" IN 81600 ROUND TRIPS.
18" TRAP ROCK BALLAST.
15" SANDY LOAM.
SETTLED 8 3/8" IN 49932 TRIPS.
12" TRAP ROCK BALLAST.
ENGINE CINDER 24" FREE FROM CLINKERS.
12" SANDY LOAM.
SETTLED 9 1/8" IN 45500 TRIPS.
12" TRAP ROCK BALLAST.
ENGINE CINDER 12" FREE FROM CLINKERS.
12" SANDY LOAM.
SETTLED 2 3/8" IN 40100 TRIPS.
8" TRAP ROCK BALLAST.
12" ENGINE CINDER
15" BAD YELLOW CLAY.
SETTLED 10 5/8" IN 81600 ROUND TRIPS.
24" TRAP ROCK BALLAST.
14" SANDY LOAM.
SETTLED 8 1/8" IN 49932 TRIPS.
ENGINE CINDER 24" FREE FROM CLINKERS.
12" SANDY LOAM.
SETTLED 7 3/4" IN 45500 TRIPS.
ENGINE CINDER 24" FREE FROM CLINKERS.
12" SANDY LOAM.
SETTLED 2 3/8" IN 40100 TRIPS.

FIG. 4-a.

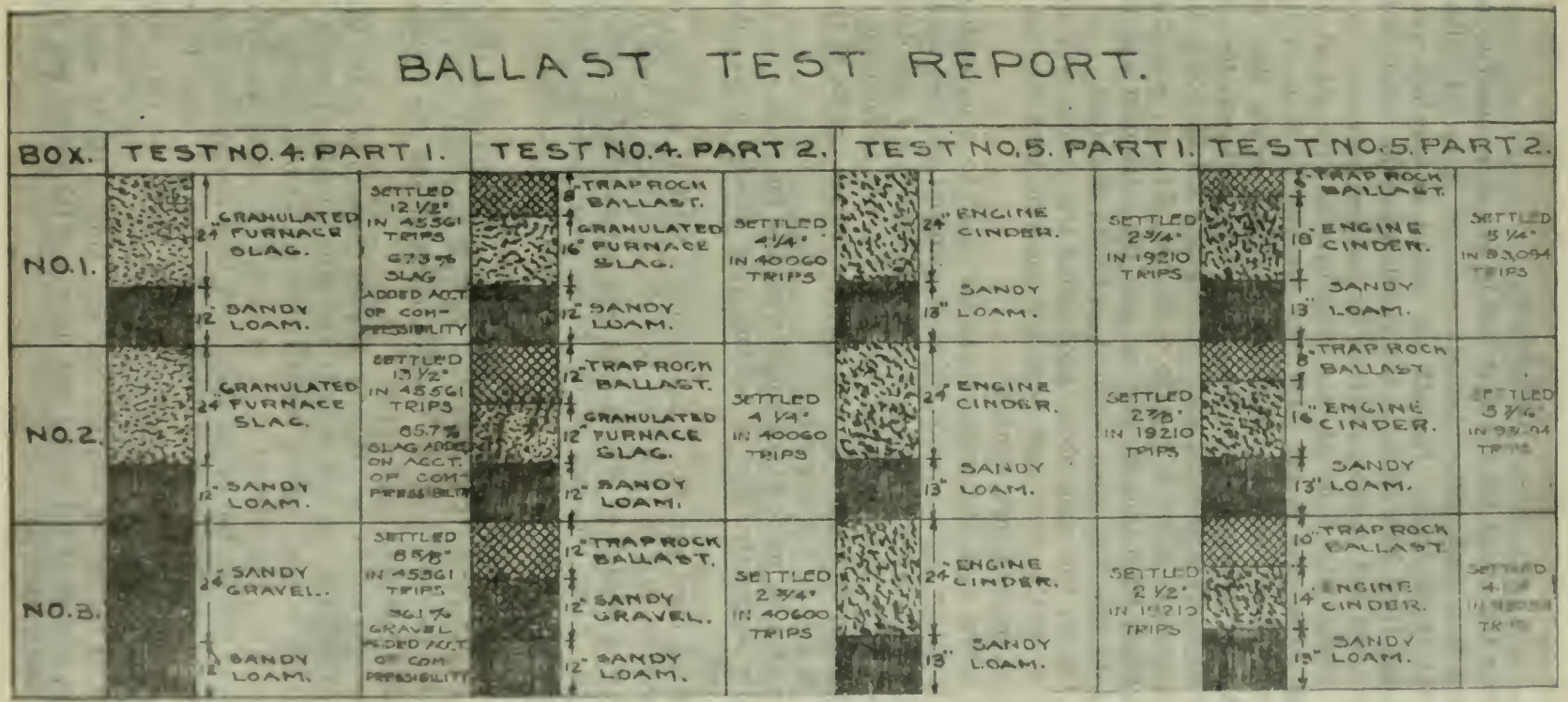

BALLAST TEST REPORT.
BOX.
TEST NO. 4. PART 1.
TEST NO. 4. PART 2.
TEST NO. 5. PART 1.
TEST NO. 5. PART 2.
NO. 1.
24" GRANULATED FURNACE SLAG.
12" SANDY LOAM.
SETTLED 12 1/2" IN 45561 TRIPS
67.3% SLAG ADDED ACCT OF COMPRESSIBILITY
8" TRAP ROCK BALLAST.
16" GRANULATED FURNACE SLAG.
12" SANDY LOAM.
SETTLED 4 1/4" IN 40060 TRIPS
24" ENGINE CINDER.
18" SANDY LOAM.
SETTLED 2 3/4" IN 19210 TRIPS
8" TRAP ROCK BALLAST.
18" ENGINE CINDER.
13" SANDY LOAM.
SETTLED 5 1/4" IN 83,064 TRIPS
NO. 2.
24" GRANULATED FURNACE SLAG.
12" SANDY LOAM.
SETTLED 13 1/2" IN 45561 TRIPS
65.7% SLAG ADDED ON ACCT. OF COMPRESSIBILITY
12" TRAP ROCK BALLAST.
12" GRANULATED FURNACE SLAG.
12" SANDY LOAM.
SETTLED 4 1/4" IN 40060 TRIPS
24" ENGINE CINDER.
13" SANDY LOAM.
SETTLED 2 3/8" IN 19210 TRIPS
8" TRAP ROCK BALLAST.
16" ENGINE CINDER.
13" SANDY LOAM.
SETTLED 5 3/16" IN 83,064 TRIPS
NO. 3.
24" SANDY GRAVEL.
12" SANDY LOAM.
SETTLED 8 5/8" IN 45561 TRIPS
36.1% GRAVEL ADDED ACCT OF COMPRESSIBILITY
12" TRAP ROCK BALLAST.
12" SANDY GRAVEL.
12" SANDY LOAM.
SETTLED 2 3/4" IN 40600 TRIPS
24" ENGINE CINDER.
13" SANDY LOAM.
SETTLED 2 1/2" IN 19210 TRIPS
10" TRAP ROCK BALLAST.
14" ENGINE CINDER.
13" SANDY LOAM.
SETTLED 4 1/8" IN 83,064 TRIPS

FIG. 4-b.

TEST NO. I.

In filling the boxes for the first test it was determined to use 8 in. of standard trap rock ballast beneath each tie, 8 in. of ballast being standard for single track. Beneath the ballast in one box were 27 in. of yellow clay from Neff's Cut on the Middle Division, which had proved itself a very bad and unstable material for roadbed purposes. In the second box, beneath the 8 in. of trap rock ballast, were placed 27 in. of good sandy loam, and in the third box, beneath the 8 in. of trap rock ballast, were placed 12 in. of engine cinder, and below that 15 in. of yellow clay, the same as in the first box. The track was then surfaced by the use of tamping picks, brought up to grade and the boxes filled with standard trap rock ballast to the top of the tie. The car was started and elevations taken from time to time to note the settlement and the track was raised, by tamping, when required, as before described.

After the car had made about 4,000 round trips, water was applied by sprinkling it equally over each box, first applying each day an amount equivalent to one-half inch rainfall.

After a few days this amount was increased to 2 in. each day and continued daily for quite a period, when the amount was increased to 4 in. per day for about a week, then 8 in. per day applied for two days, in the hope of producing pumping track, but this was not accomplished for the reason that the water found its way out between the cracks of the planking about as fast as it was put in.

The car having made 81,600 round trips and the track over the boxes being nearly stationary, that is, settling very slowly, it was decided to close the test.

The track over box No. 1 had settled a total of $10\frac{9}{16}$ in.; over box No. 2, a total of $14\frac{1}{16}$ in., and over box No. 3, a total of $10\frac{5}{8}$ in. Water equivalent to a rainfall of $98\frac{1}{4}$ in. had been sprinkled over each box during the test. After the ends of the boxes were removed, sections and photographs were taken, which are fully shown in the account of test No. 1 in the appendix.

An inspection of the boxes showed that in every case the depth of the ballast beneath the bottom of the tie had been materially increased, due to the compression of the roadbed material and the sinking of the ballast into the material beneath it.

Further, the line of demarkation between the bottom of the ballast and the roadbed material was not straight, the ballast having formed a saucer-like depression in the roadbed material beneath each tie under each rail.

In box No. 3 the original 12 in. of engine cinder, between the bottom of the ballast and the top of the clay, were very considerably compressed, the bottom of the ballast immediately under the rail being forced about half way through the cinder. On the other hand, the clay beneath the cinder showed very little compression and the line of demarkation between the bottom of the cinder and the clay was quite straight, while the line between the bottom of the ballast and the top of the cinder was very much depressed under each tie.

The test showed conclusively that a depth of 8 in. of standard trap rock ballast, when laid on the usual roadbed material, was not sufficient to distribute the weight carried by the ties uniformly over the roadbed.

The results in the third box showed, however, that if 12 in. of permeable material, such as soft coal engine cinder, were used beneath the 8 in. of ballast, the distribution of the weight over the roadbed material was much better, as is shown by the cross-sections and photographs.

The results of the first test led to the conclusion that a second test should be conducted to determine how a depth of 12 in., 18 in. and 24 in. of trap rock ballast under the ties would behave.

The experience gained from the first test suggested that better results would be obtained by using sandy loam beneath the ballast rather than yellow clay, because the first test showed that the sandy loam was more compressible than the yellow clay and that the line dividing the ballast and the loam was easier to study than the line dividing the ballast and the clay.

TEST NO. 2.

The boxes were again filled, No. 1 box having 12 in. of trap rock ballast beneath the tie, with 26 in. of loam underneath it; box No. 2 having 18 in. of ballast under the tie, with 19 in. of loam beneath it; and box No. 3 having 24 in. of ballast under the tie, with 14 in. of loam beneath it.

The car was started running on April 18, 1909, and practically the same method was pursued as in test No. 1, already described. During the test, water equivalent to 11¾ in. of rainfall was applied. After the car had made 49,932 round trips, it was stopped on June 15, 1909, because the track over the boxes settled very slowly. The boxes were opened and photographs and measurements made, as are shown in the report of test No. 2, in the appendix.

An inspection of the boxes clearly showed that in box No. 1, having 12 in. of ballast beneath the tie, the lower surface of the ballast had been compressed a considerable distance into the loam, and that the line dividing the two was far from straight, there being a considerable depression in the line beneath each tie, especially under the rail.

In box No. 2, where there were 18 in. of ballast originally under the tie, the ballast had not been driven so far down into the loam and the dividing line was much straighter.

In box No. 3, having 24 in. of standard trap rock ballast beneath the tie, the amount of ballast settlement was still less and the line between it and the loam quite straight.

In test No. 2, measurements were taken to show cross-sections at right angles to the rail, one through the middle of each tie and one through the center between the two ties.

An inspection of these sections will confirm the conclusion already reached, as it will be noticed the deeper the ballast, the straighter the line between it and the loam.

After a careful consideration of the data presented by the second test,

the conclusion seems inevitable that with standard stone ballast nothing less than 24 in. beneath the tie will distribute the weight of the load uniformly over the sub-grade or roadbed. On the other hand, test No. 1 had shown that a depth of 8 in. of stone and 12 in. of cinder gave apparently fair results in distributing the weight upon the sub-grade.

TEST NO. 3.

It was therefore decided to fill No. 1 box with 24 in. of cinder beneath the ties and 12 in. of loam below that; No. 2 box and No. 3 box the same; to run a number of trips over each box and then remove from No. 1 box 8 in. of cinder beneath the tie and substitute for it 8 in. of standard trap rock ballast; in No. 2 box to remove 12 in. of cinder and substitute for it 12 in. of ballast and allow No. 3 box to remain without any change in the materials and then run a number of trips over each box. The object in running on the engine cinder before putting in the stone ballast was to compact it in a similar manner to actual service conditions when the track is first ballasted with engine cinder and later raised out of the cinder upon standard stone ballast.

No. 3 test was started on June 28, 1909, and when the car had made 45,500 round trips it was stopped and the cinder removed and stone ballast put in boxes Nos. 1 and 2, as described above.

The car was then started and 40,100 round trips were made, water being applied at a rate equivalent to about one-half inch of rainfall per day until a total of 15¾ in. had been sprinkled over each box.

In the previous tests it had been noted that the water found its way through the stone ballast to the top of the clay or loam beneath it and there collected and ran through the cracks between the planks.

In making the third test a new feature was introduced in one of the boxes by placing therein, on top of the loam, beneath the 24 in. of cinder, two pieces of iron pipe perforated with many holes. Each piece of pipe sloped from the center of the box outward to the ends of the box, a slot being made in each end of the box opposite the end of the pipe, so that it could be watched.

When the test was started, on June 28, 1909, water equivalent to one-half inch of rainfall was applied daily. This was in progress for nine days, until water equivalent to a total rainfall of 4¾ in. had been sprinkled on box No. 3 before any moisture appeared at the ends of the iron pipe, and then only a very small quantity of slime began to ooze out at the ends. At no time during the test did water run freely from the ends of these pipes. This was considered a very significant fact, inasmuch as it showed the ability of engine cinders to absorb and dissipate a large amount of water falling upon it before the water was able to reach the sub-grade in sufficient quantities to do much damage by saturating it. During the experiments the pipes were carefully watched and kept clean from the inside, so that any water reaching them could be observed.

On August 6, 1909, after 85,600 round trips had been made and water equivalent to 15¾ in. of rainfall had been sprinkled on each of the boxes,

they were opened, sections measured and photographs taken, as shown in report of test No. 3, in the appendix.

A study of the sections and photographs as to the line separating the engine cinder and the loam, showed that in box No. 3, where cinder was continued through the entire test and no stone ballast substituted, the line between the cinder and the loam was the straightest or best, showing the least amount of cupping, and that the line between the cinder and the loam in boxes Nos. 1 and 2 left very little to choose between them, with a difference, we think, slightly in favor of box No. 2. At the same time it should be clearly noted that the sections taken at right angles to the track show the ties bent more in box No. 3 than they did in either boxes No. 1 or No. 2, due to the fact that engine cinder is more compressible than broken trap rock.

A study of the lines of demarkation, between the trap rock ballast and engine cinder in boxes Nos. 1 and 2, develops that there was less deformation or cupping of the cinder beneath the ties where the depth of stone ballast had originally been 12 in. in box No. 2 than where 8 in. in box No. 1.

TEST NO. 4.

It was determined upon the conclusion of test No. 3 that it would be well to test two other materials available for use as sub-ballast, namely, granulated slag and gravel, to see how they would compare with engine cinder under similar conditions. Therefore test No. 4 was started, boxes Nos. 1 and 2 having 24 in. of granulated slag under the ties and 12 in. of loam beneath that; box No. 3 having 24 in. of a sandy New Jersey gravel procured along the Bonhampton Branch of the New York Division. After the boxes were filled practically the same method was pursued as in test No. 3. It was noted that the compressibility of gravel was about equal to that of engine cinder, while that of granulated slag was much greater.

After 45,561 round trips had been made by the car, boxes Nos. 1 and 2, respectively, had 8 in. and 12 in. of trap rock ballast put in beneath the ties and on top of the granulated slag, while box No. 3 had 12 in. of standard trap rock ballast put in on top of the gravel. The car was again started and run for 40,060 round trips.

After a total of 85,621 round trips had been made and water equivalent to 14 in. of rainfall had been sprinkled over each box, the car was stopped on December 3, 1909, the boxes opened, sections measured and photographs taken, as before described.

This test developed the superiority of gravel when used for sub-ballast, as compared with granulated slag, the granulated slag being much more compressible and unstable than the gravel. There was little difference, however, in the line dividing the slag and the loam, and the gravel and the loam. This would seem to indicate that neither material had much advantage over the other in distributing the pressure upon the loam. A further study of this line showed that in box No. 2, where, during the latter half of the test, there were 12 in. of trap rock ballast beneath the tie,

the line between the slag and the loam was a trifle better than where there were only 8 in. beneath the tie in box No. 1.

An inspection of the line, dividing the trap rock ballast and slag in boxes Nos. 1 and 2, and the ballast and the gravel in box No. 3, showed that there was more cupping or deformation where the ballast was only 8 in. deep beneath the tie on top of the slag than where it was 12 in. deep beneath the tie on top of the slag or gravel.

Further, the line in box No. 3, between the trap rock ballast and the gravel, was still better than between the stone ballast and the slag in box No. 2. This is also confirmed by an inspection of the sections taken at right angles to the track.

TEST NO. 5.

The data obtained from all of the tests up to this point indicate that the greater the depth of trap rock ballast, beneath the tie, at least to a depth of 24 in., the less deformation there is in the line dividing the trap rock ballast and the material directly beneath it, the best results in this respect having been shown with a depth of 24 in. of trap rock ballast beneath the tie in box No. 3 of the second test. This brought forward the proposition whether it would be possible, by a combination of trap rock ballast and engine cinder, having a total depth of 24 in., to get as good a distribution of weight or pressure on the loam as was obtained by a depth of 24 in. of standard trap rock ballast alone. And, further, would such a combination of standard trap rock ballast and engine cinder show too much deformation of the line separating the stone and the engine cinder?

To determine this, if possible, test No. 5 was started with 24 in. of engine cinder beneath the ties on top of 13 in. of loam in each box. The car was started running on May 19, 1910, and 19,210 round trips made to compact the engine cinder until the daily settlement of the cinder amounted to very little.

On June 24, 1910, the car was stopped and 6 in. of standard trap rock ballast were placed beneath the ties in box No. 1; 8 in. beneath the ties in box No. 2, and 10 in. beneath the ties in box No. 3. The ballast was tamped with tamping picks as in all the previous tests. The car was run until a total of 112,304 round trips had been made and water equivalent to a rainfall of 18½ in. had been sprinkled over each box. On August 2, 1910, the car was stopped, the track having, for several days prior, shown very little settlement. The boxes were opened, and the usual measurements made and photographs taken.

The fifth test showed that there was less total settlement in box No. 3, where the depth of the stone ballast was the greatest, namely, 10 in. beneath the tie. Also, that there was less deformation or cupping between the line of engine cinder and the loam, and between the line of ballast and the engine cinder, but the line between the engine cinder and the loam in box No. 3 was not as good as the line between the ballast and the loam in box No. 3 of test No. 2, where there were 24 in. of trap rock ballast beneath the tie and on top of the loam. This indicates that 24 in. of trap rock ballast beneath the tie will distribute the pressure upon the sub-grade

more uniformly than a like depth of trap rock ballast and compressed engine cinder combined, up to the point where the layer of engine cinder has a thickness of not less than 14 in., and it is our opinion that any layer of engine cinder, having a less depth than 14 in., would be sufficient to produce the results desired by the use of engine cinder, viz., a layer of material beneath the stone ballast which will absorb, lead off and dissipate water falling upon the track before it can reach the roadbed proper in sufficient quantities to be injurious.

A depth of 24 in. of standard trap rock ballast, beneath which is an additional layer or mat, 24 in. thick, of good permeable material, will place our sub-grade at a depth below the average frost line obtaining in the latitude in which the greater part of our system is located, thereby eliminating the trouble due to the action of the frost upon the roadbed and track.

Since the amount of wear and tear imposed on the experimental track and sub-soil during the various tests was very small compared with that to which our main line tracks are subjected under service conditions, your Committee recommends the use of 24 in. of stone ballast underneath the ties to meet satisfactorily the conditions that exist to-day and which will probably become more severe as time goes on, and that in addition to the 24 in. of trap rock ballast beneath the ties, there should be provided a layer of engine cinder, gravel or an equivalent, to act as an absorbent mat to promptly and properly dispose of the water falling on the track in such a manner as to prevent its softening the roadbed material. Where the material forming the roadbed is of poor quality, the mat of engine cinder or gravel will also prove advantageous to prevent its working up into the ballast, thus shutting off drainage.

APPENDIX.

TEST NO. 1.

September 2, 1908, to January 5, 1909.

MATERIAL IN BOXES.

Box No. 1—8 in. of trap rock ballast under the ties and 27 in. of bad yellow clay below.

Box No. 2—8 in. of trap rock ballast under ties and 27 in. of sandy loam below.

Box No. 3—8 in. of trap rock ballast under ties; 12 in. of engine cinder under ballast and 15 in. of bad yellow clay below cinder.

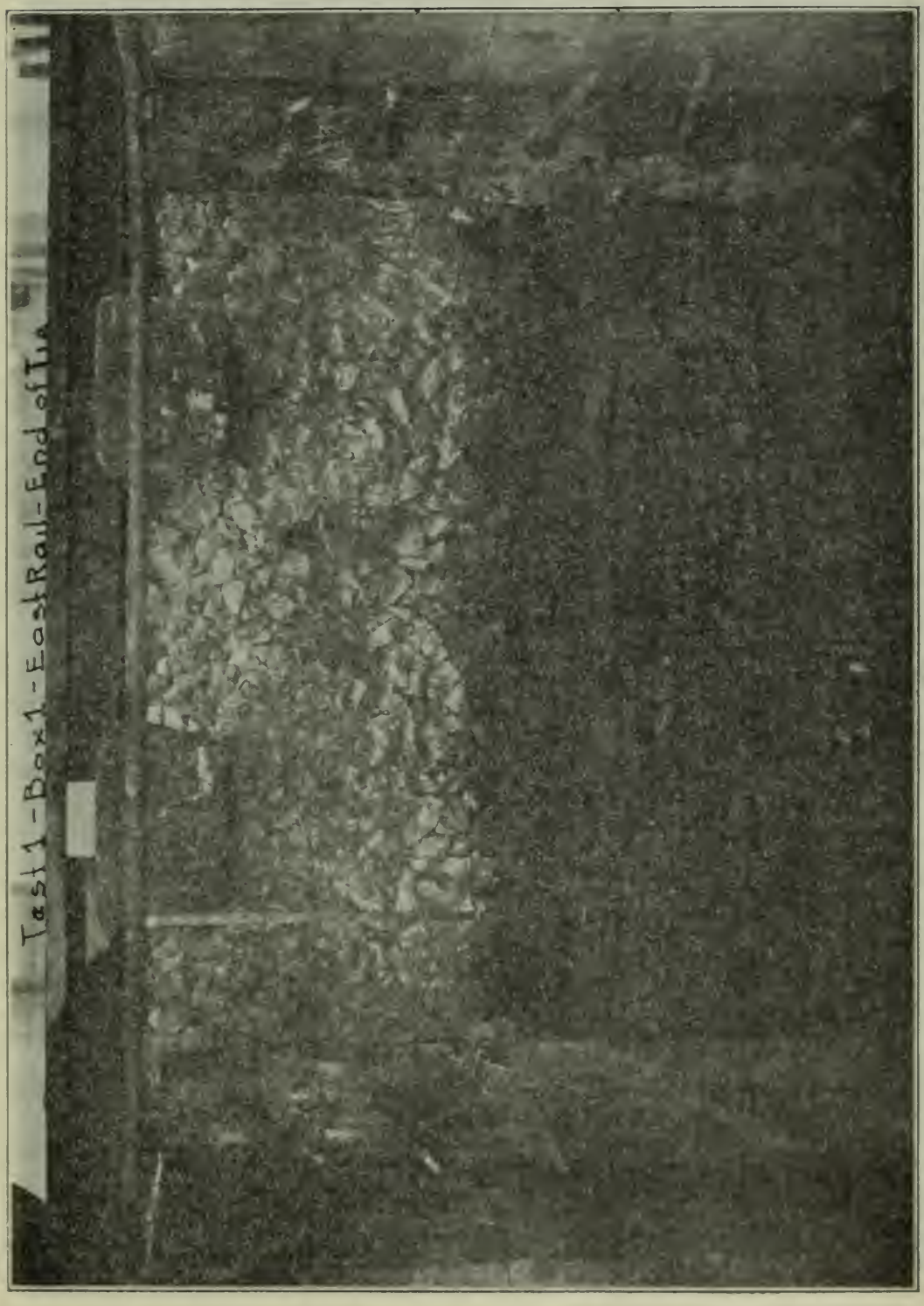
The car was started on September 2, 1908, and was run at various intervals, making approximately 500 round trips to October 2, when a register was placed on the car for recording the number of trips made.

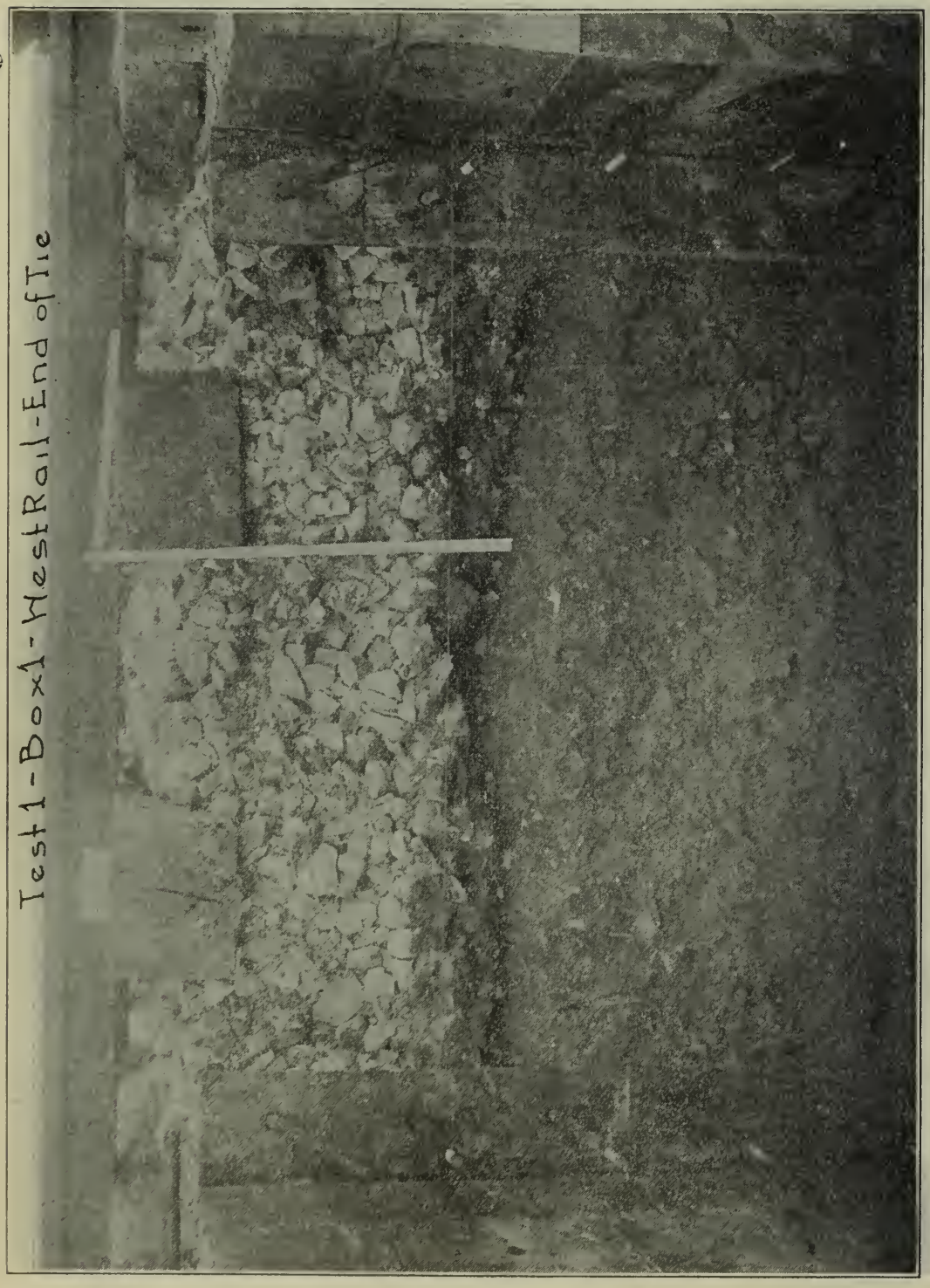
The total settlement for the 81,600 round trips was as follows:

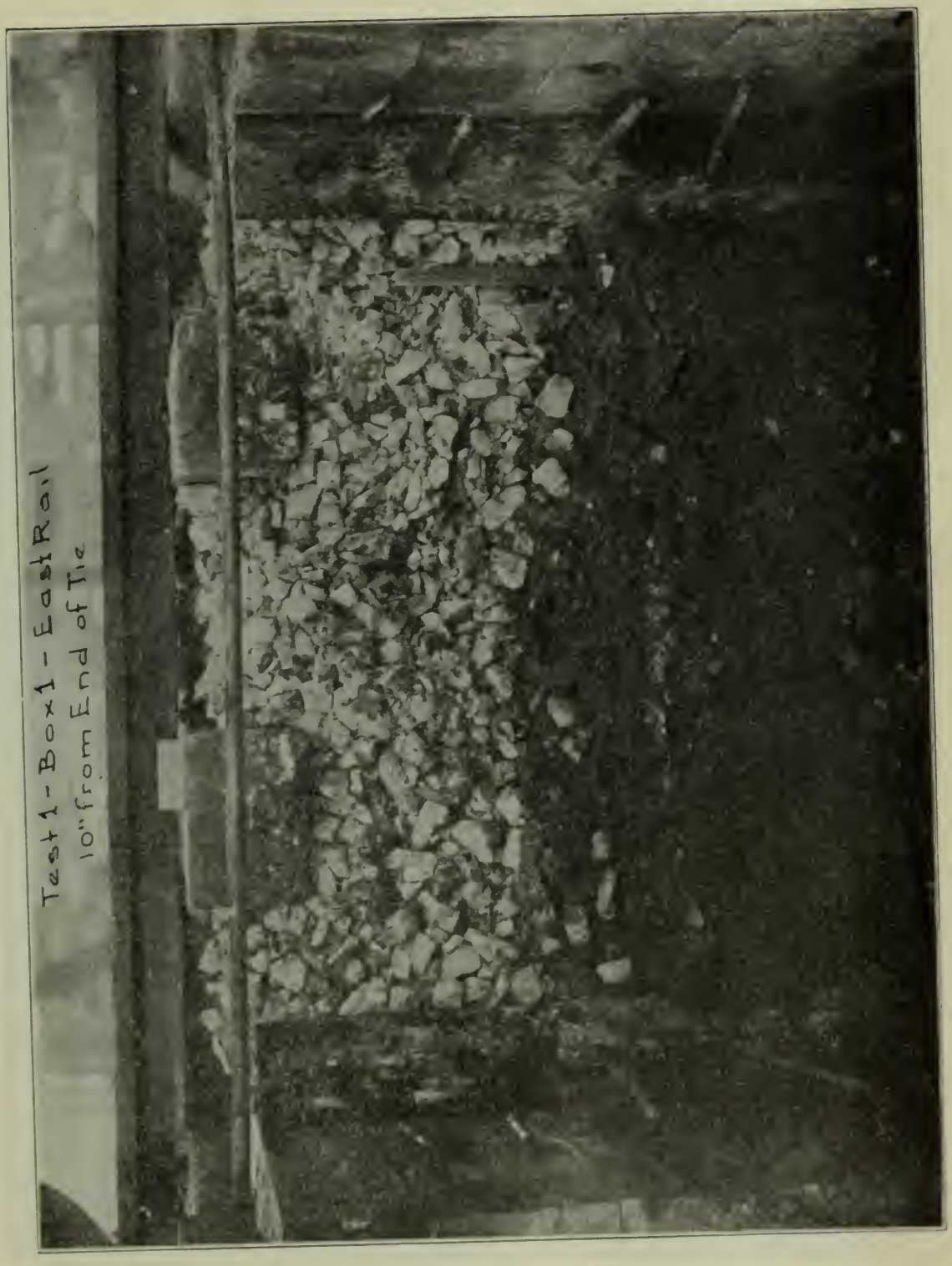
Box No. 1—10 9/16 in.
Box No. 2—14 1/16 in.
Box No. 3—10 5/8 in.

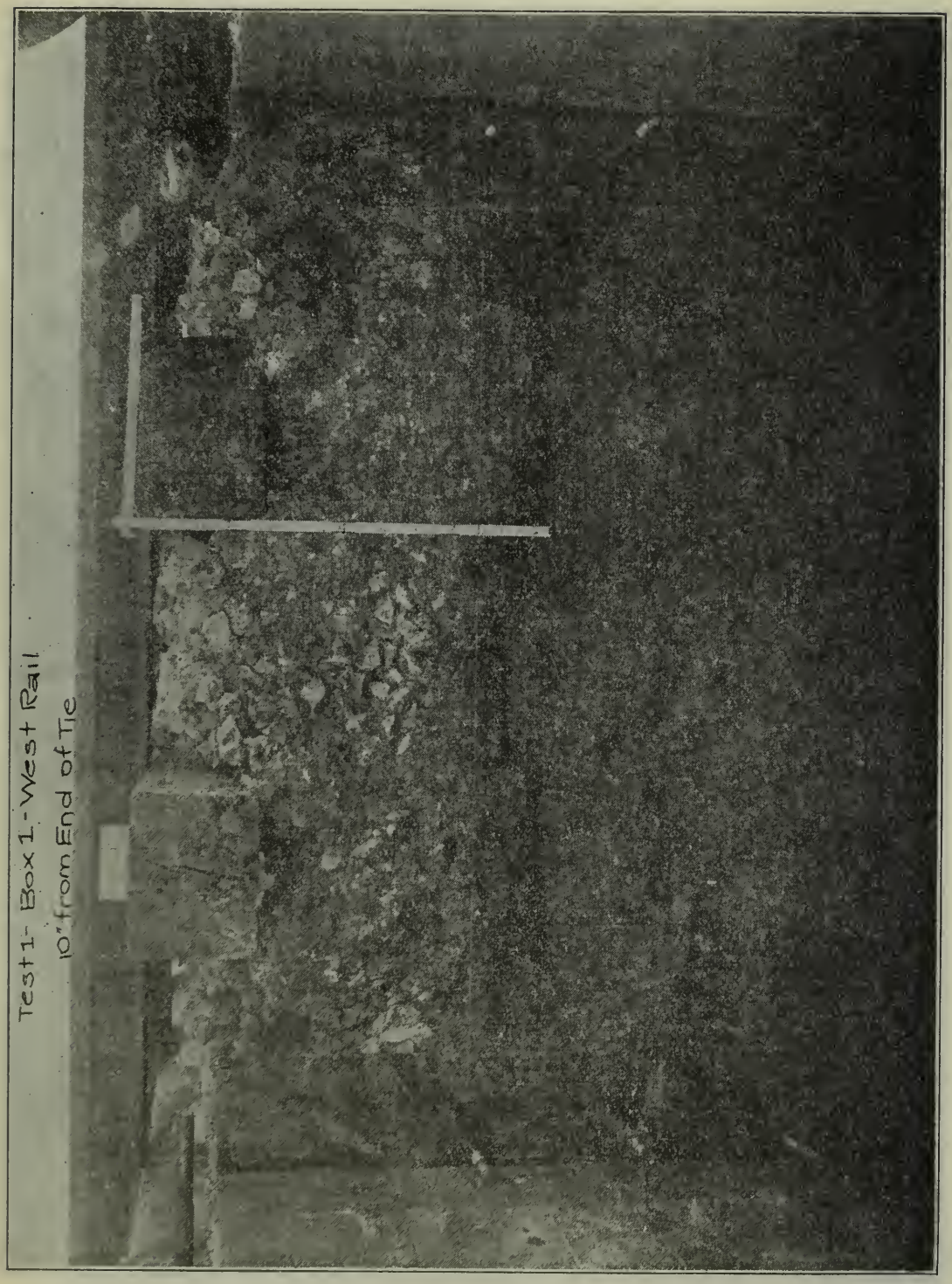
After 4,000 round trips, water in definite quantities was sprayed equally on each box daily. A total amount of water equivalent to 98¼ in. of rainfall was used.

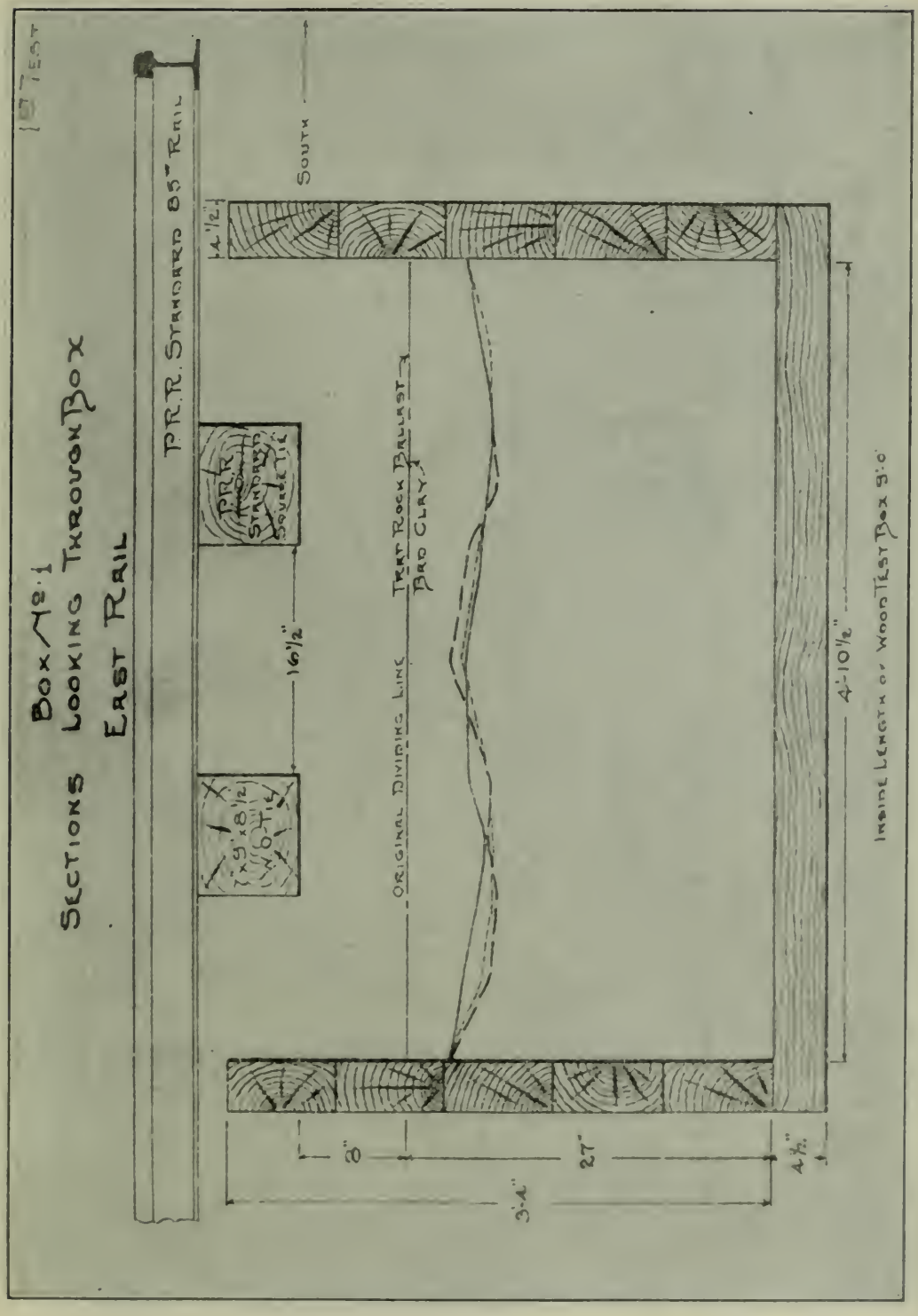
On January 5, 1909, freezing weather made it impracticable to obtain any further results, and as the settlement curves showed a tendency to run horizontally, the first test was closed.

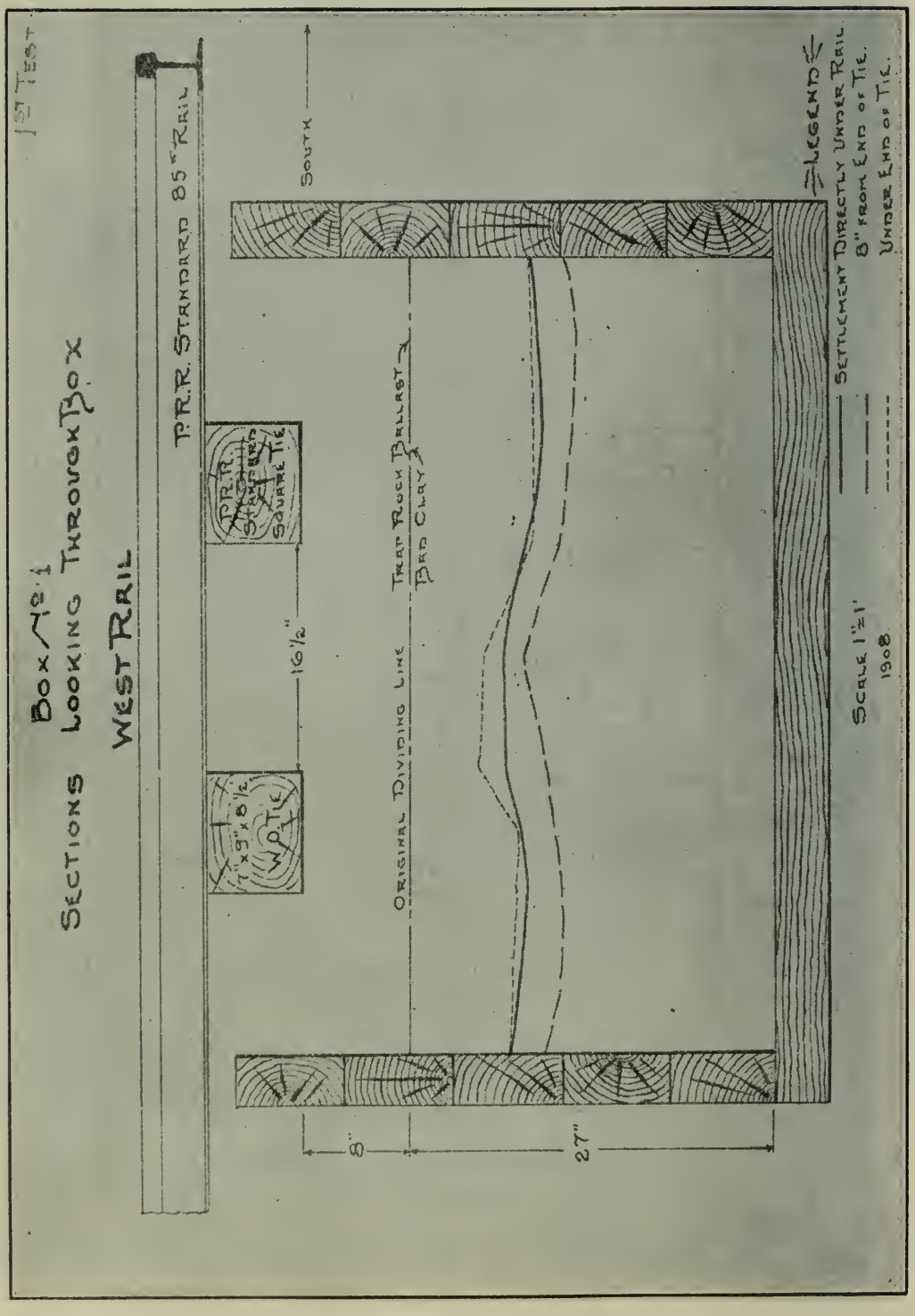

Test 1 - Box 1 - East Rail - End of Tie

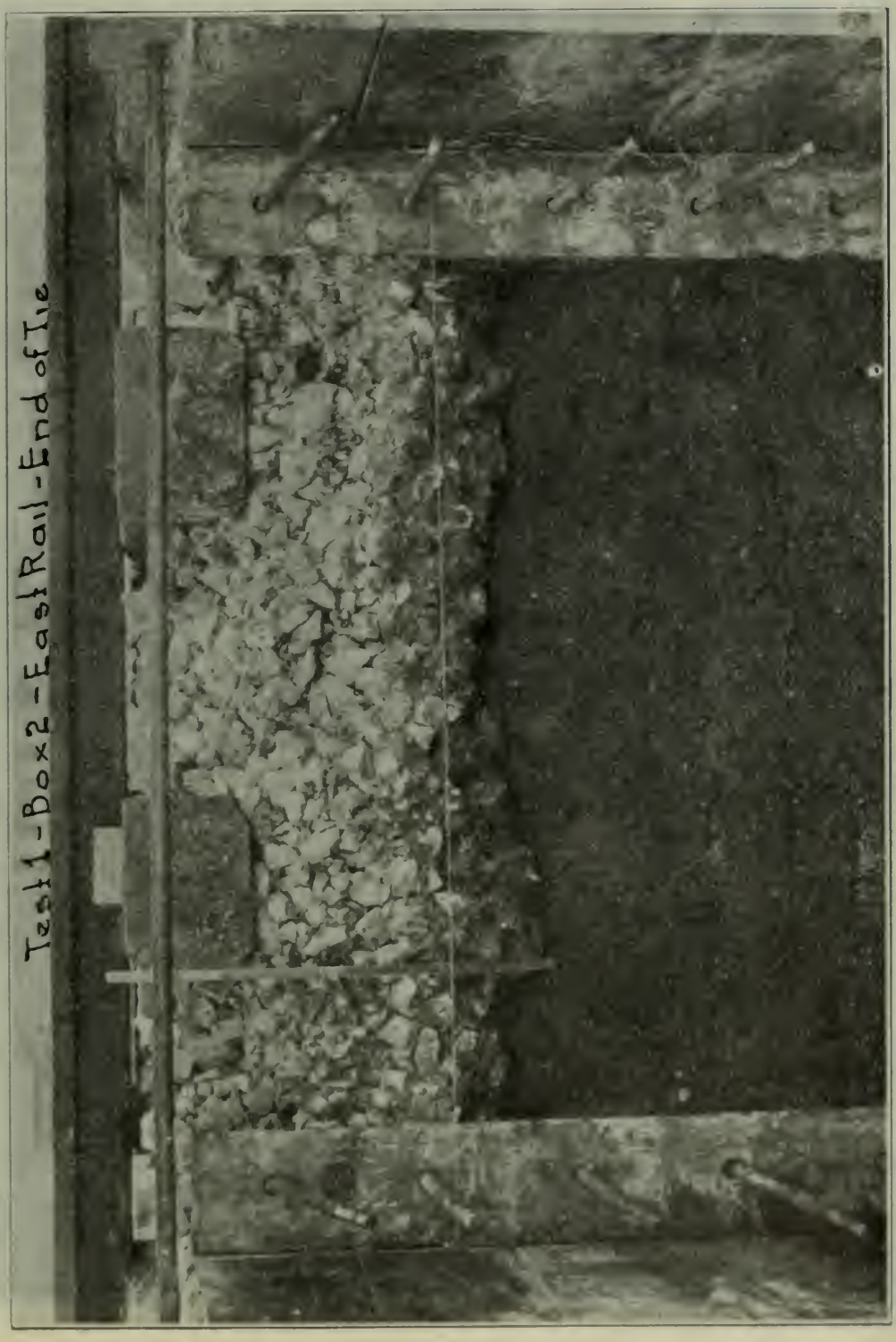

Test 1-Box 1-West Rail-End of Tie

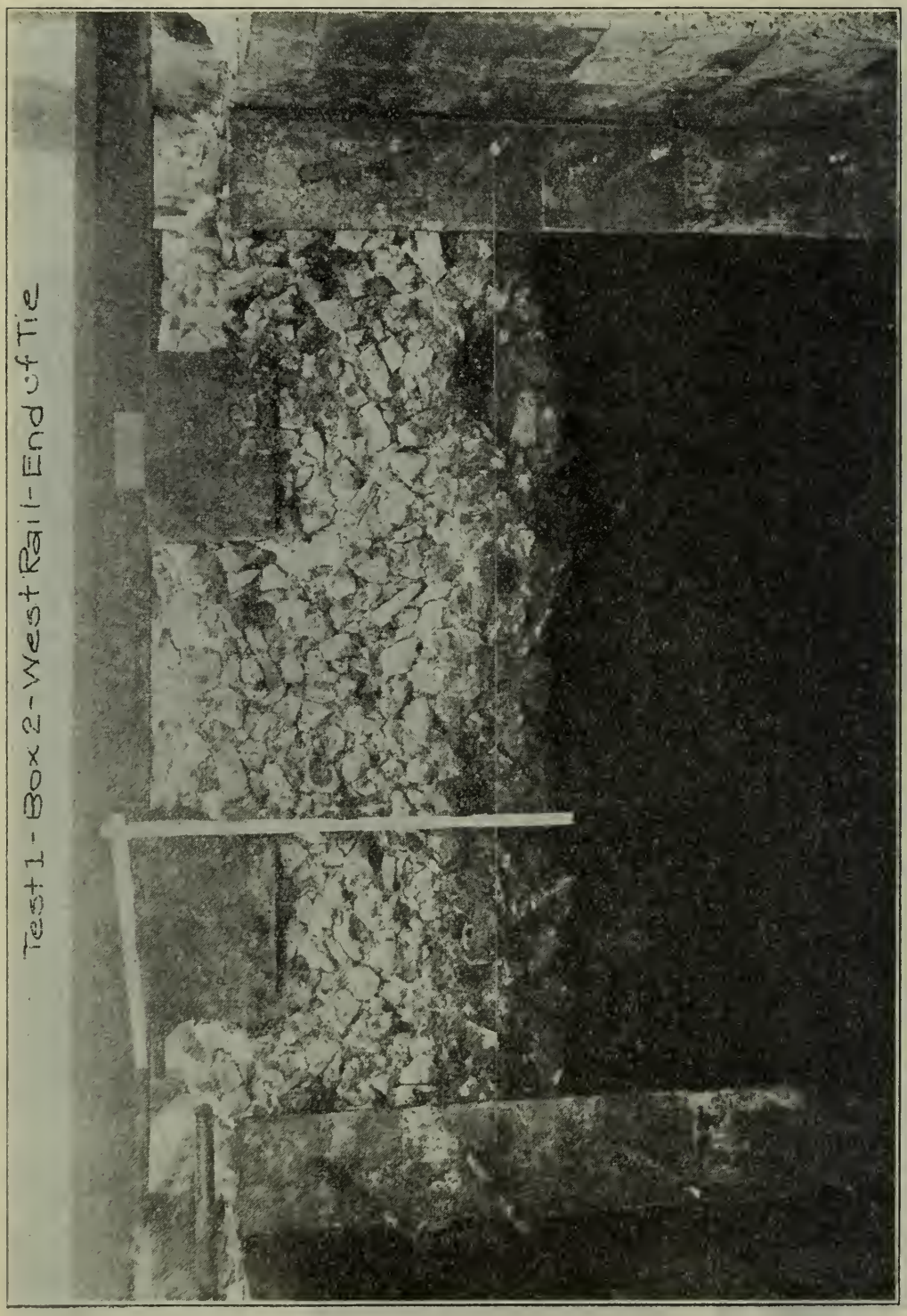

Test 1 - Box 1 - East Rail
10" from End of Tie

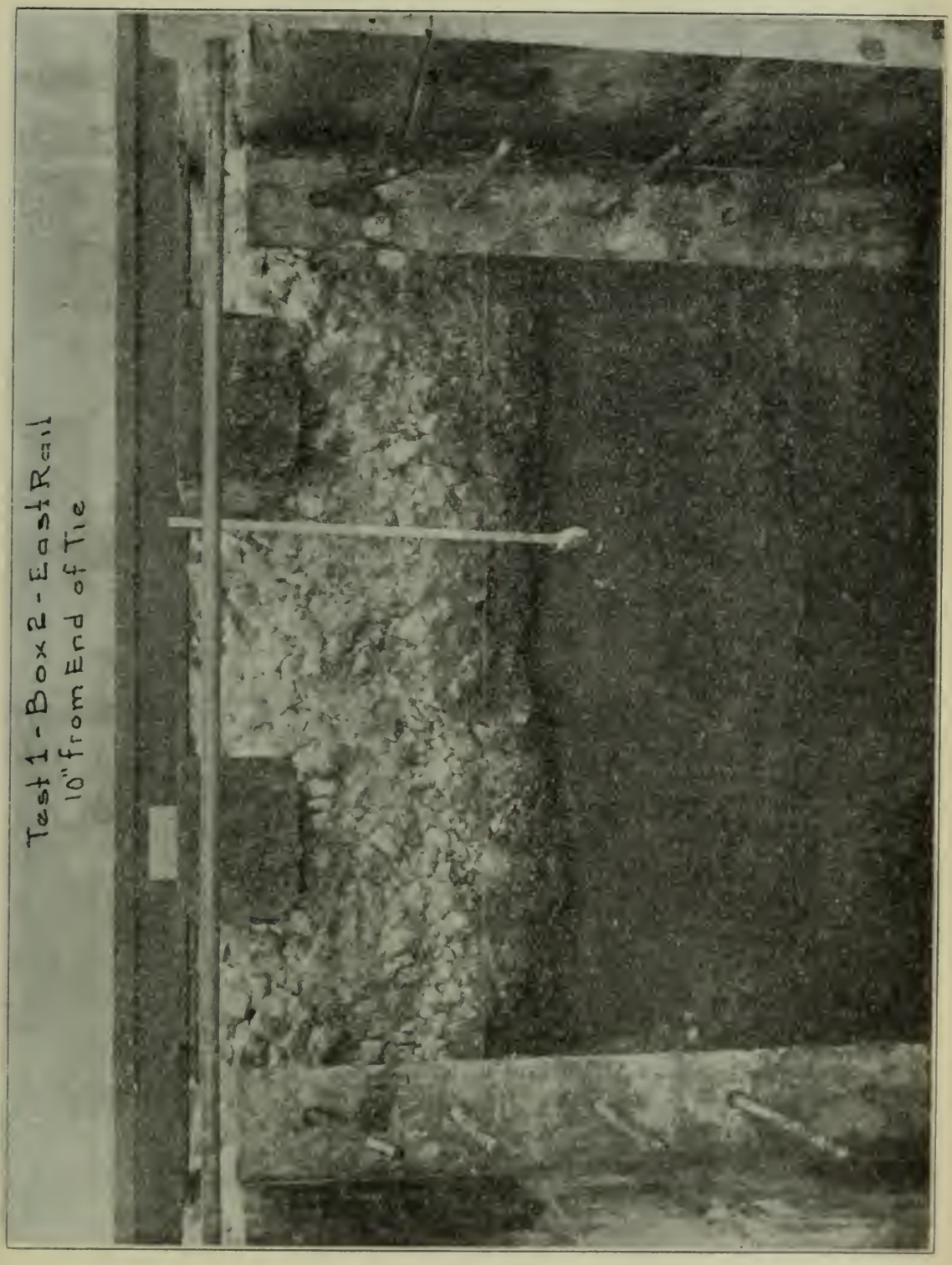

Test 1- Box 1- West Rail
10" from End of Tie

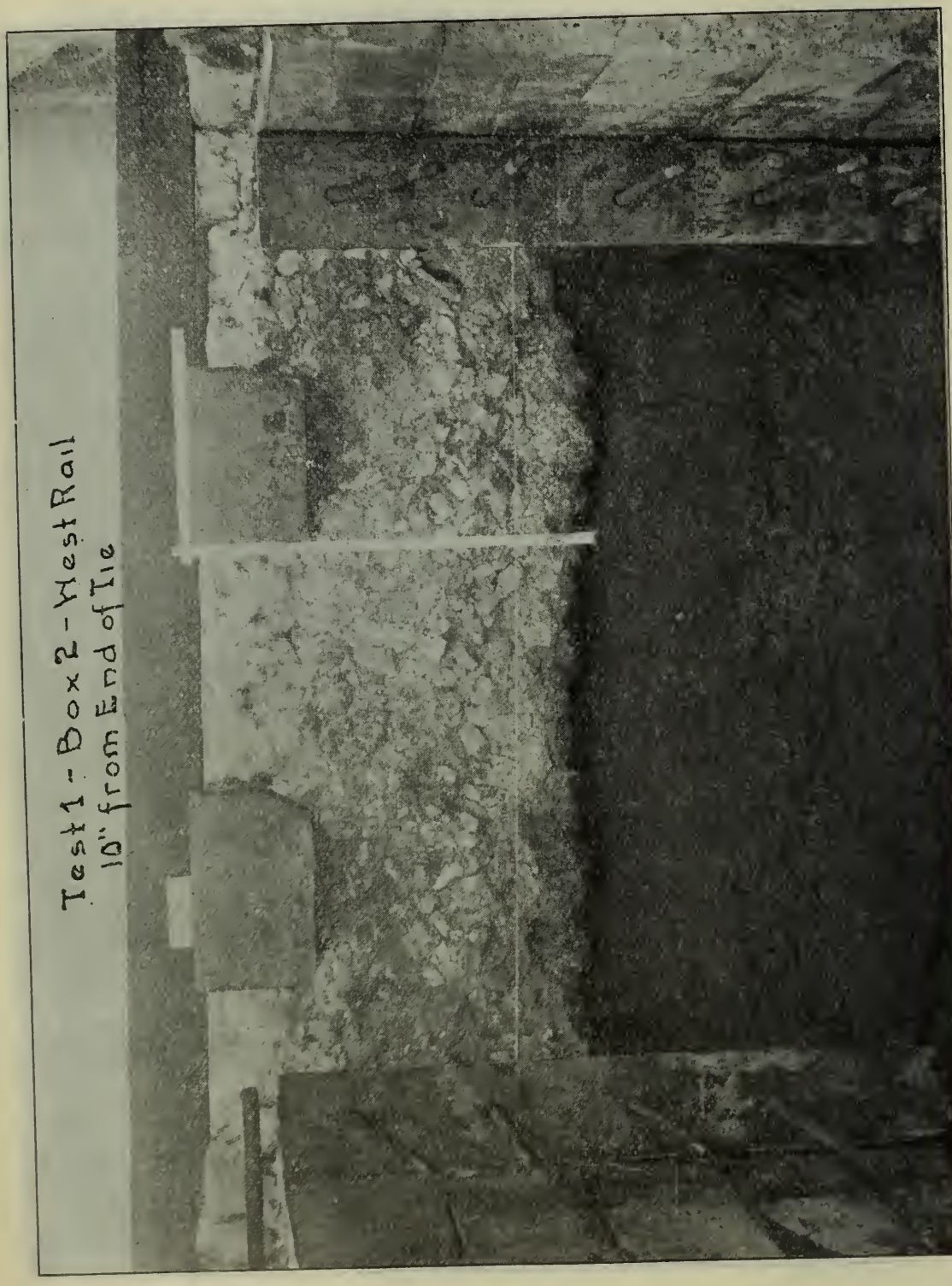

Box A2-1
Sections Looking Through Box
East Rail
P.R.R. Standard 85# Rail
South
14-1/2"
P.R.R. Standard Tie
16-1/2"
7"x9"x8-1/2" Wooden Tie
Original Dividing Line
Trap Rock Ballast
Red Clay
4'-10½"
Inside Length of Wood Test Box 9'-0"
3"
27"
4½"
3'-1"

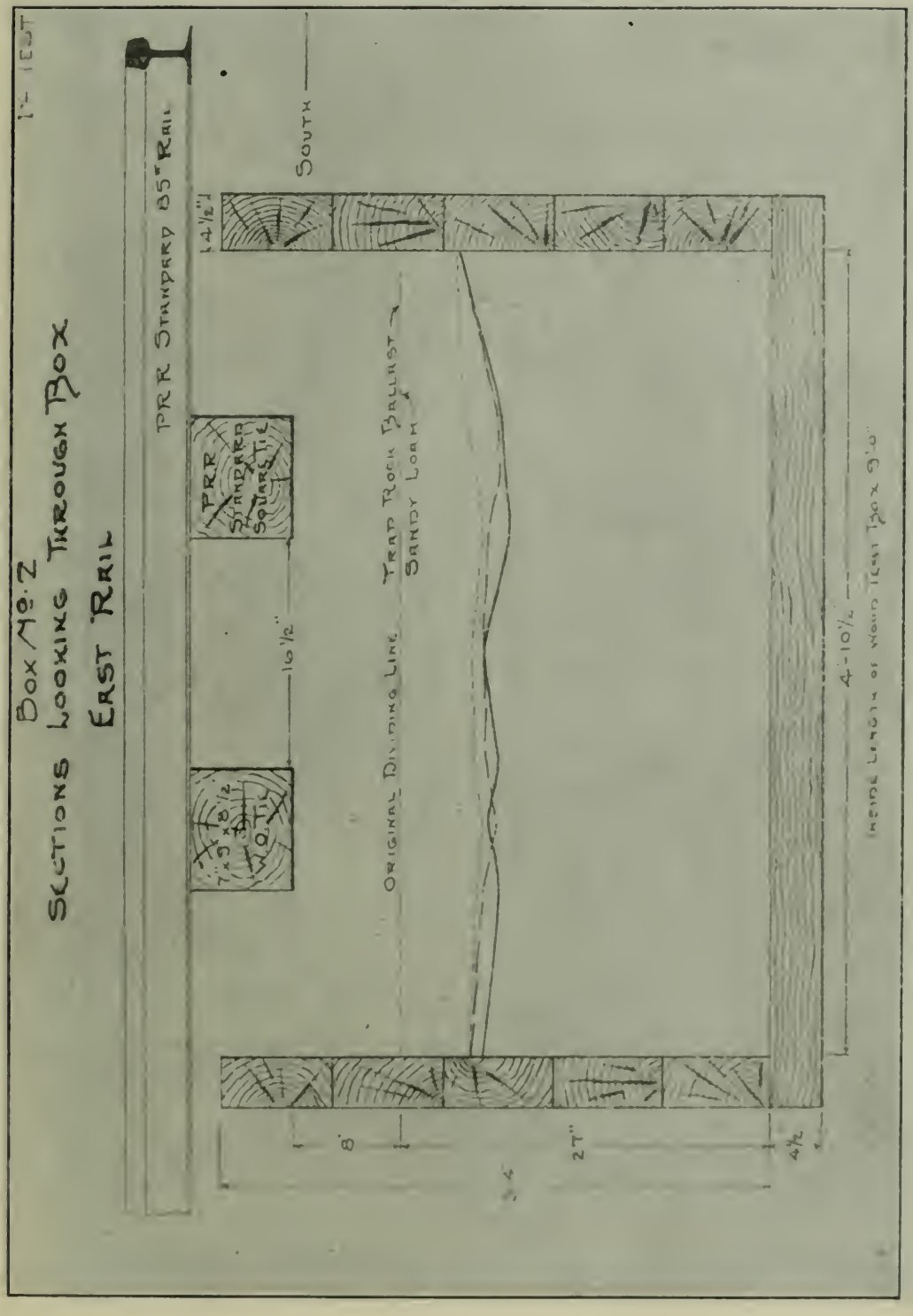

1st Test
Box No. 1
Sections Looking Through Box
West Rail
P.R.R. Standard 85# Rail
South
P.R.R. Standard Steel Tie
7"x9"x8½" White Oak Tie
16½"
Original Dividing Line
Trap Rock Ballast
Red Clay
8"
27"
Legends
Settlement Directly Under Rail
8" from End of Tie.
Under End of Tie.
Scale 1"=1'
1908.

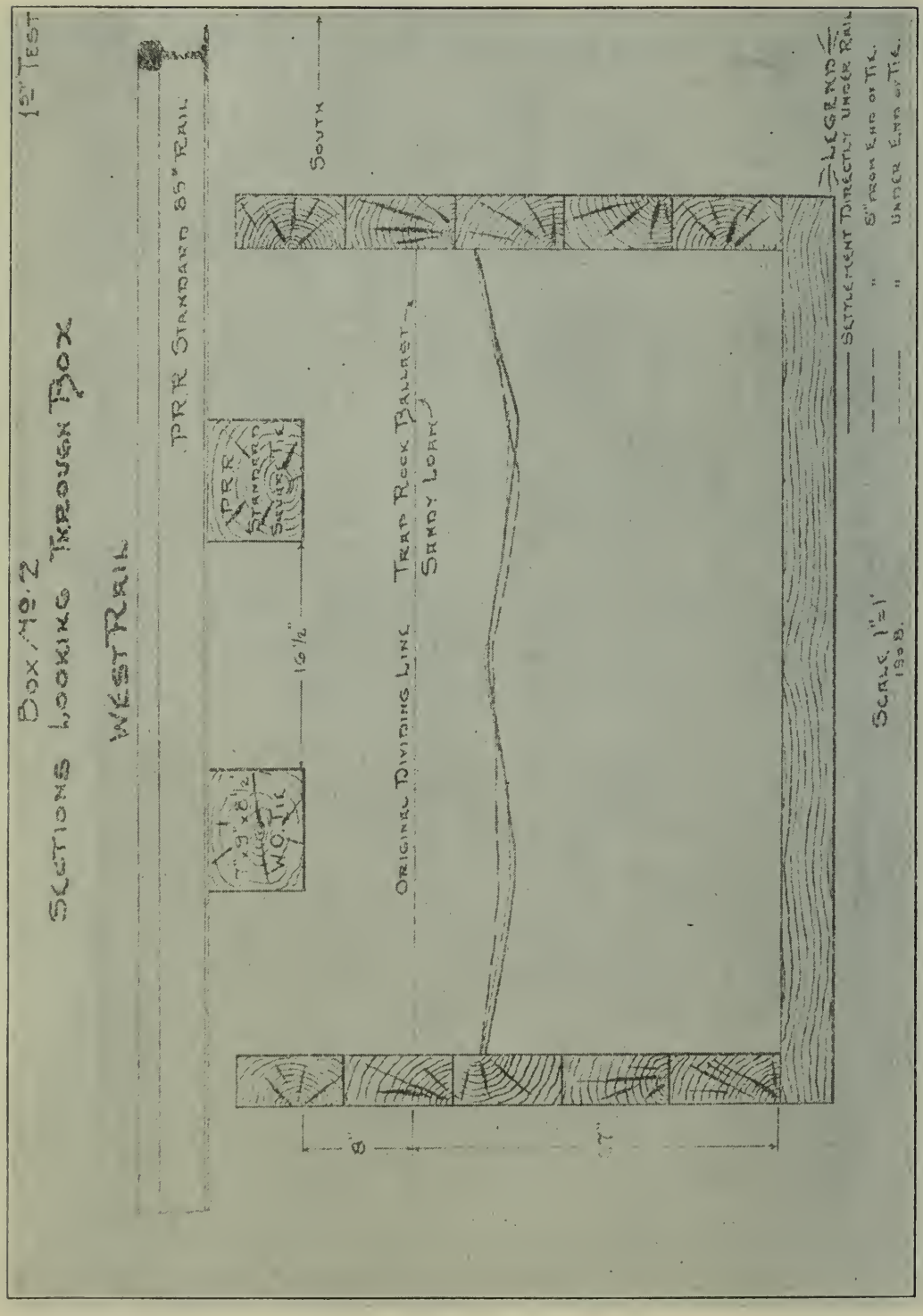

Test 1 - Box 2 - East Rail - End of Tie

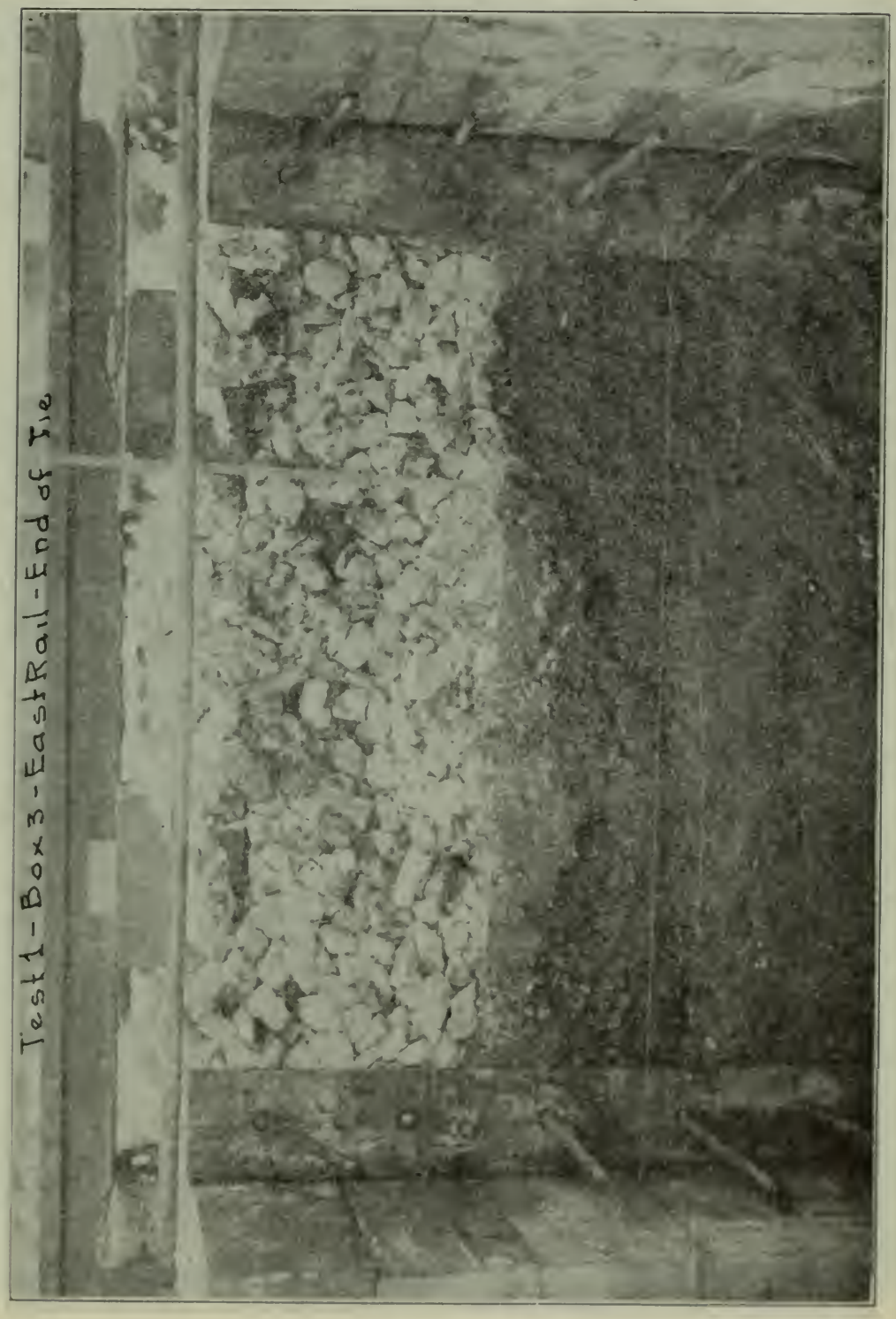

Test 1 - Box 2 - West Rail - End of Tie

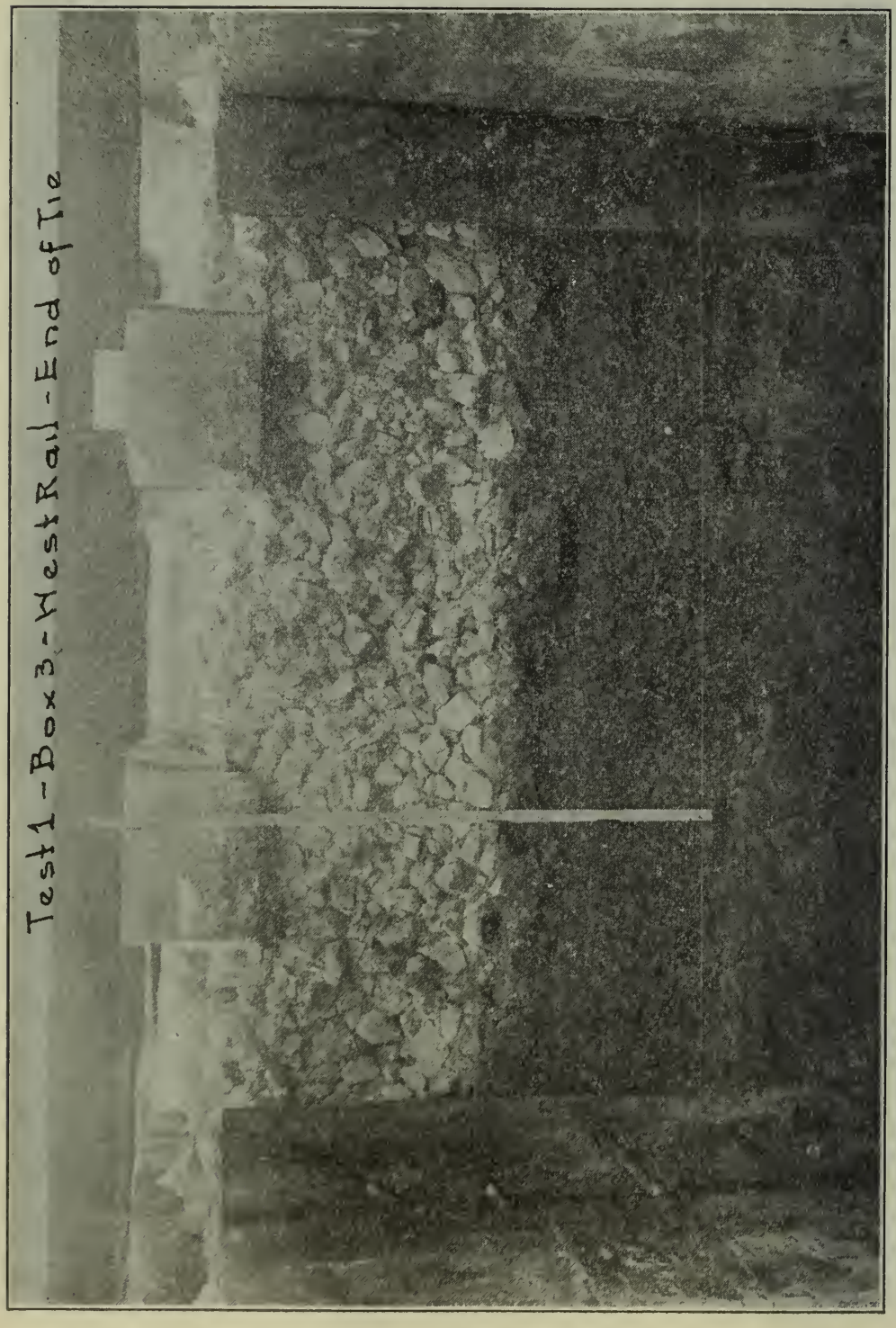

Test 1 - Box 2 - East Rail
10" from End of Tie

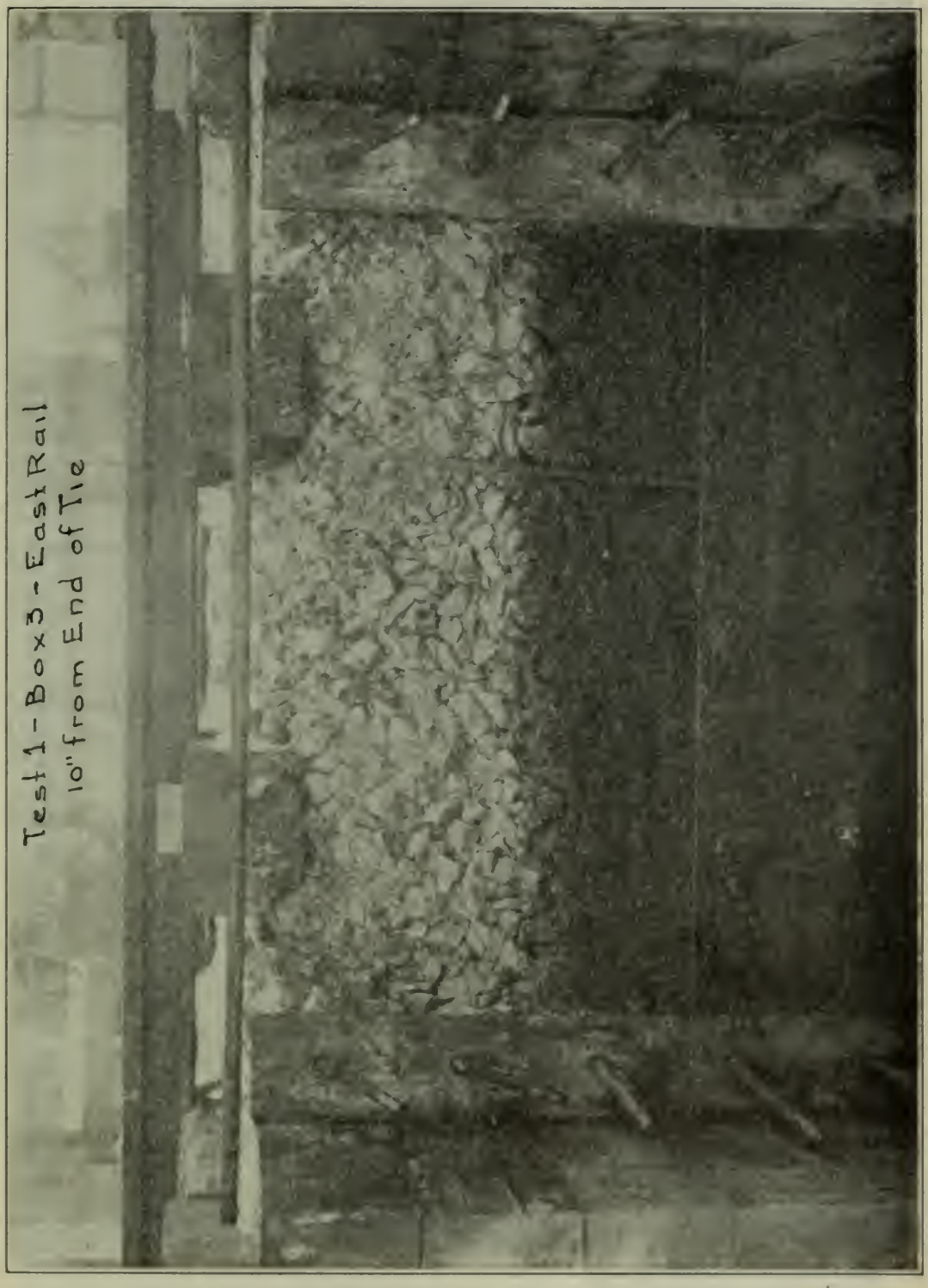

Test 1 - Box 2 - West Rail
10" from End of Tie

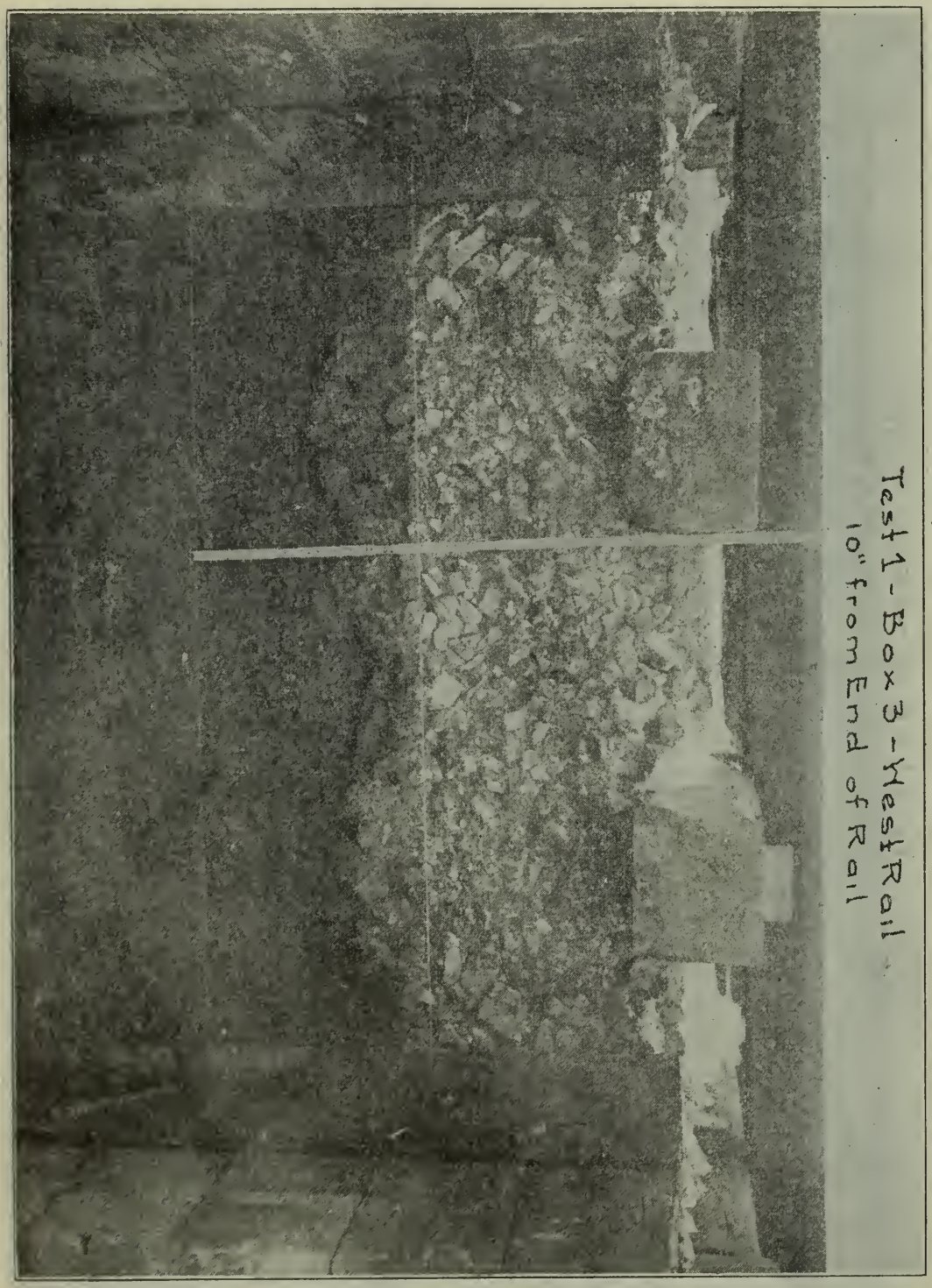

Box No. 2
Sections Looking Through Box
East Rail
PRR Standard 85# Rail
South
PRR Standard Square Tie
Original Dividing Line
Trap Rock Ballast
Sandy Loam
10½"
8"
27"
4½
4-10½
Inside Length of Wood Test Box 9'0"

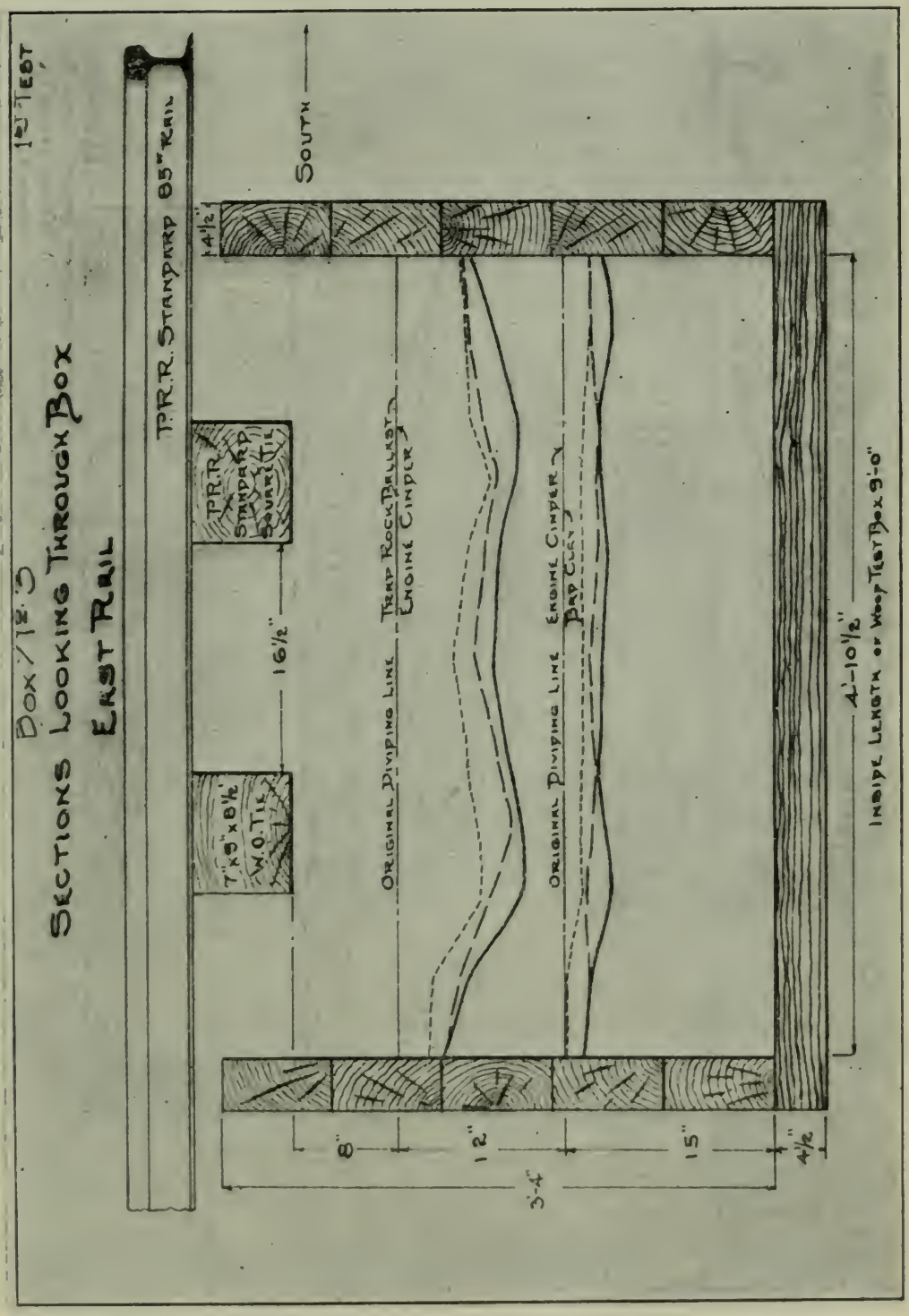

15" TEST
BOX 49.2
SECTIONS LOOKING THROUGH BOX
WEST RAIL
PRR STANDARD 85# RAIL
SOUTH
PRR STANDARD SAWED TIE
16½"
ORIGINAL DIVIDING LINE
TRAP ROCK BALLAST
SANDY LOAM
LEGEND
SETTLEMENT DIRECTLY UNDER RAIL
6" FROM END OF TIE.
UNDER END OF TIE.
SCALE 1"=1'
1908.
8'
7'

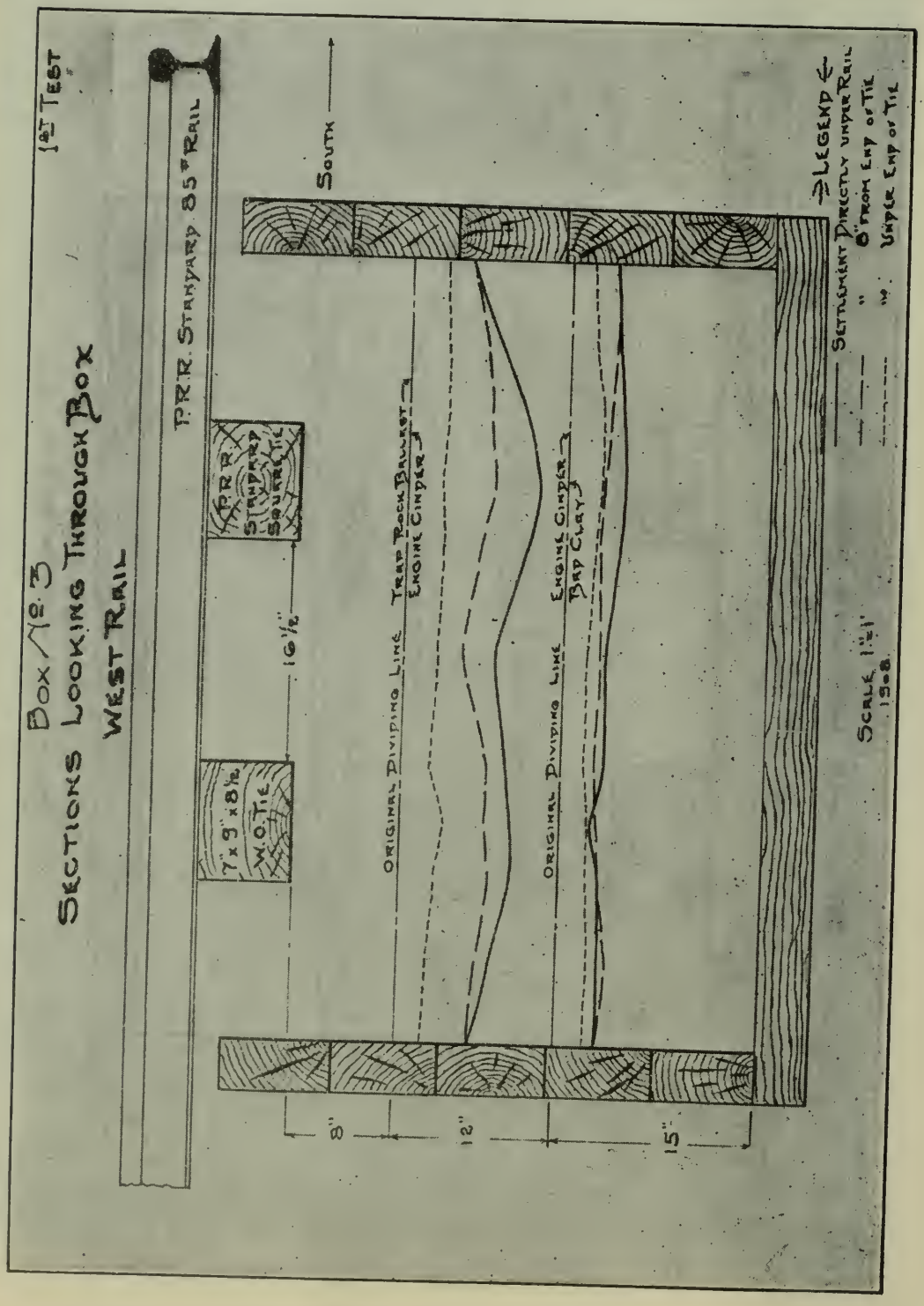

Test 1 - Box 3 - East Rail - End of Tie

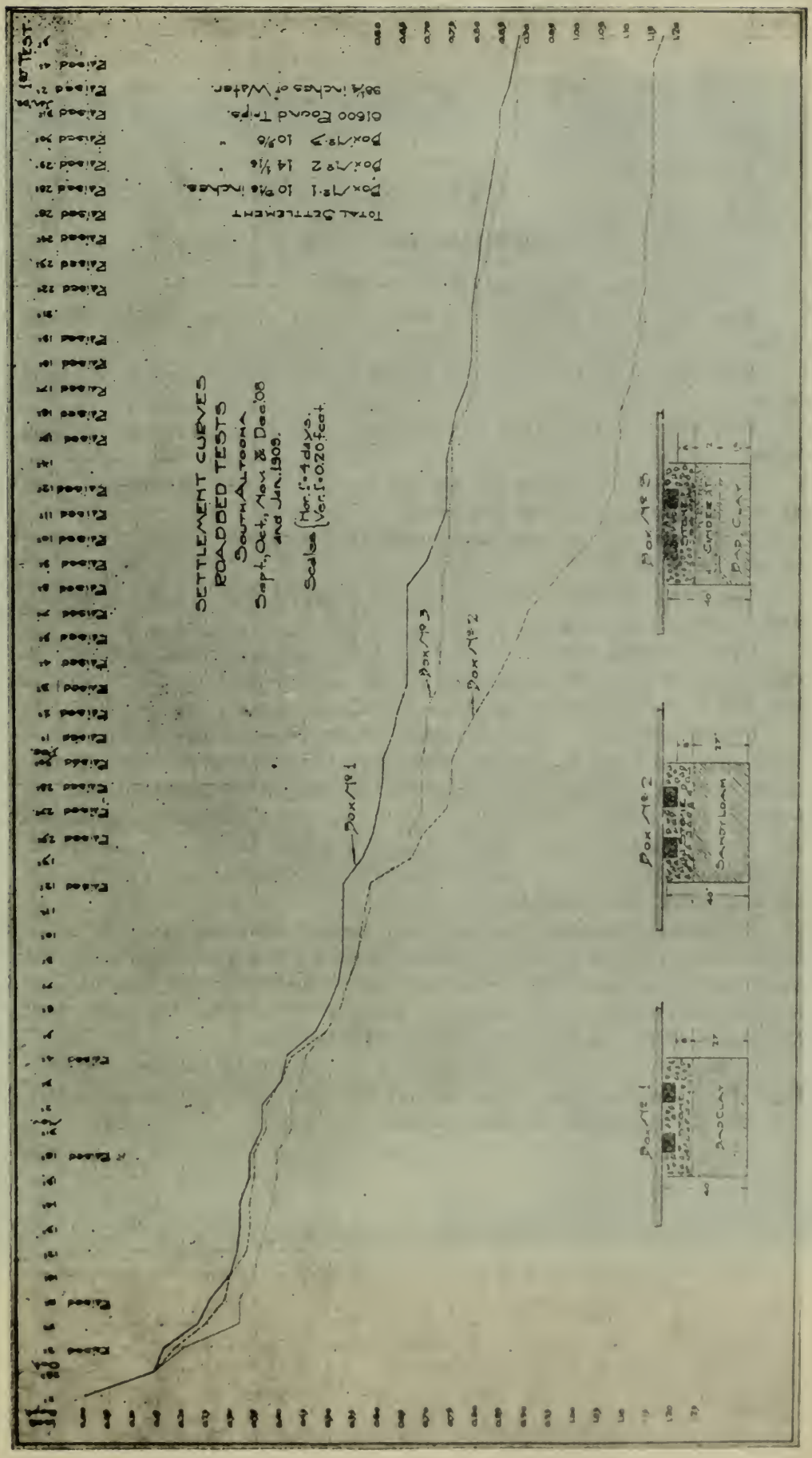

Test 1 - Box 3 - West Rail - End of Tie


Test 1 - Box 3 - East Rail
10" from End of Tie


Test 1 - Box 3 - West Rail
10" from End of Rail


1st Test
Box 12.5
Sections Looking Through Box
East Rail
P.R.R. Standard 85 lb Rail
South
14½"
7"x9"x8½" W.O. Tie
16½"
P.R.R. Standard Quarry Tie
Original Dividing Line
Temp Rock Ballast
Engine Cinder
Original Dividing Line
Engine Cinder
Pea Coal
4'-10½"
Inside Length of Wood Test Box 9'-0"
8"
12"
15"
4½"
3'-4"


1st Test
Box No. 3
Sections Looking Through Box
West Rail
P.R.R. Standard 85# Rail
South
P.R.R. Standard Square Tie
7" x 9" x 8½' W.O. Tie
16½"
Original Dividing Line
Trap Rock Ballast
Engine Cinder
Original Dividing Line
Engine Cinder
Bed Clay
8"
12"
15"
Legend
Settlement Directly under Rail
6" from End of Tie
" Under End of Tie
Scale 1"=1'
1908


SETTLEMENT CURVES
ROADBED TESTS
SOUTH ALTOONA
Sept., Oct., Nov. & Dec. '08
and Jan. 1909.
Scales (Hor. 1:4 days.
Ver. 1:0.20 feet.
TOTAL SETTLEMENT
Box No. 1 10 9/16 inches.
Box No. 2 14 1/16 "
Box No. 3 10 3/4 "
61800 Pound Trips.
38 1/4 inches of Water.
Box No. 1
Box No. 2
Box No. 3
Box No. 1
CLAY
Box No. 2
SAND LOAM
Box No. 3
CLAY

TEST NO. 2.

April 18 to June 15, 1909.

MATERIAL IN BOXES.

Box No. 1—12 in. trap rock ballast under ties and 26 in. of loam below.

Box No. 2—18 in. trap rock ballast under ties and 19 in. of loam below.

Box No. 3—24 in. trap rock ballast under ties and 14 in. of loam below.

The car was started on the 18th of April, 1909, and continued to June 15, making 49,932 trips, running in the daytime only.

Water was put on each box during the test to an amount equivalent to 11¾ in. rainfall.

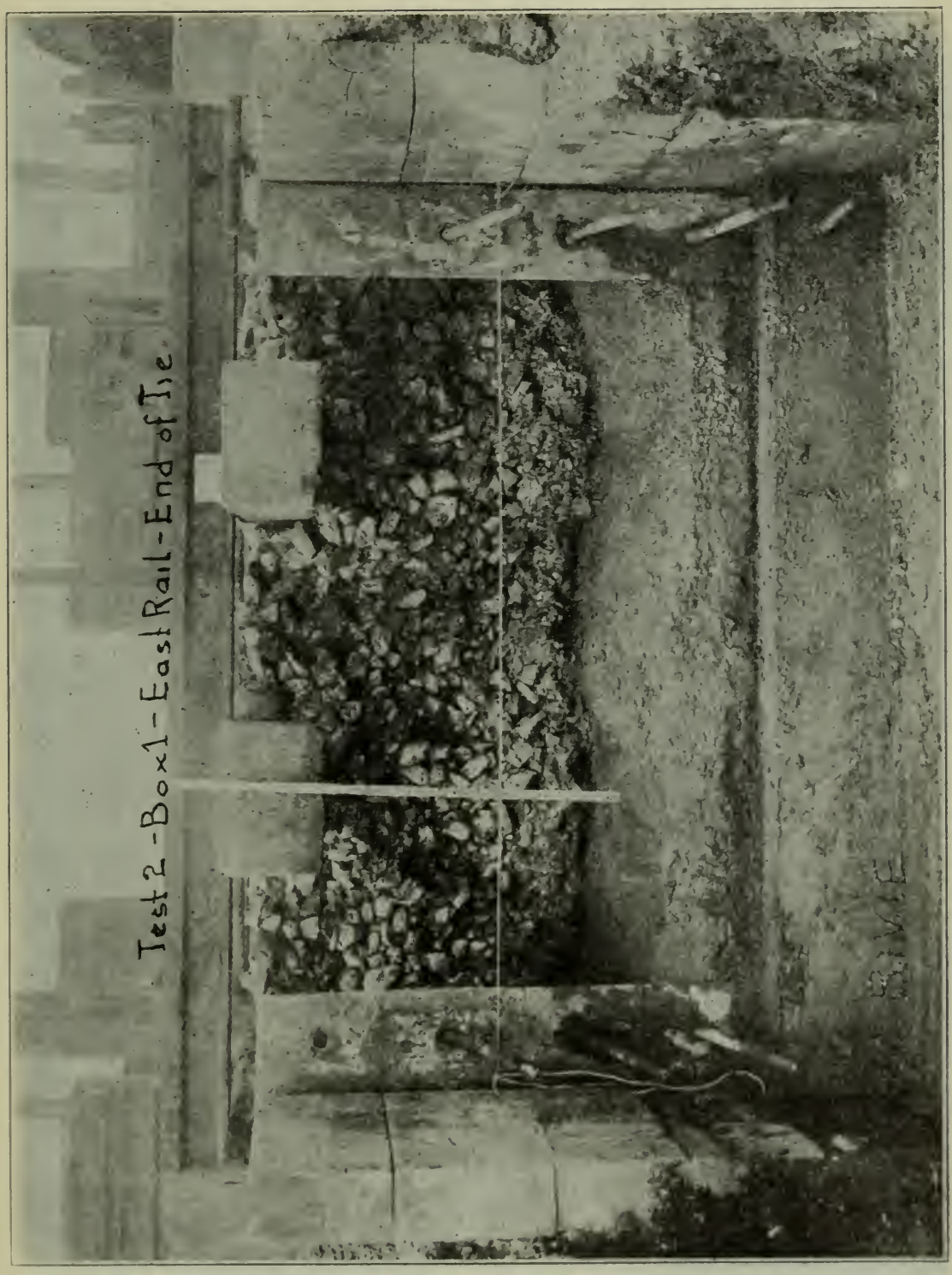
The total settlement for box No. 1 was 8⅜ in.; for box No. 2, 9⅜ in., and for box No. 3, 9⅛ in.

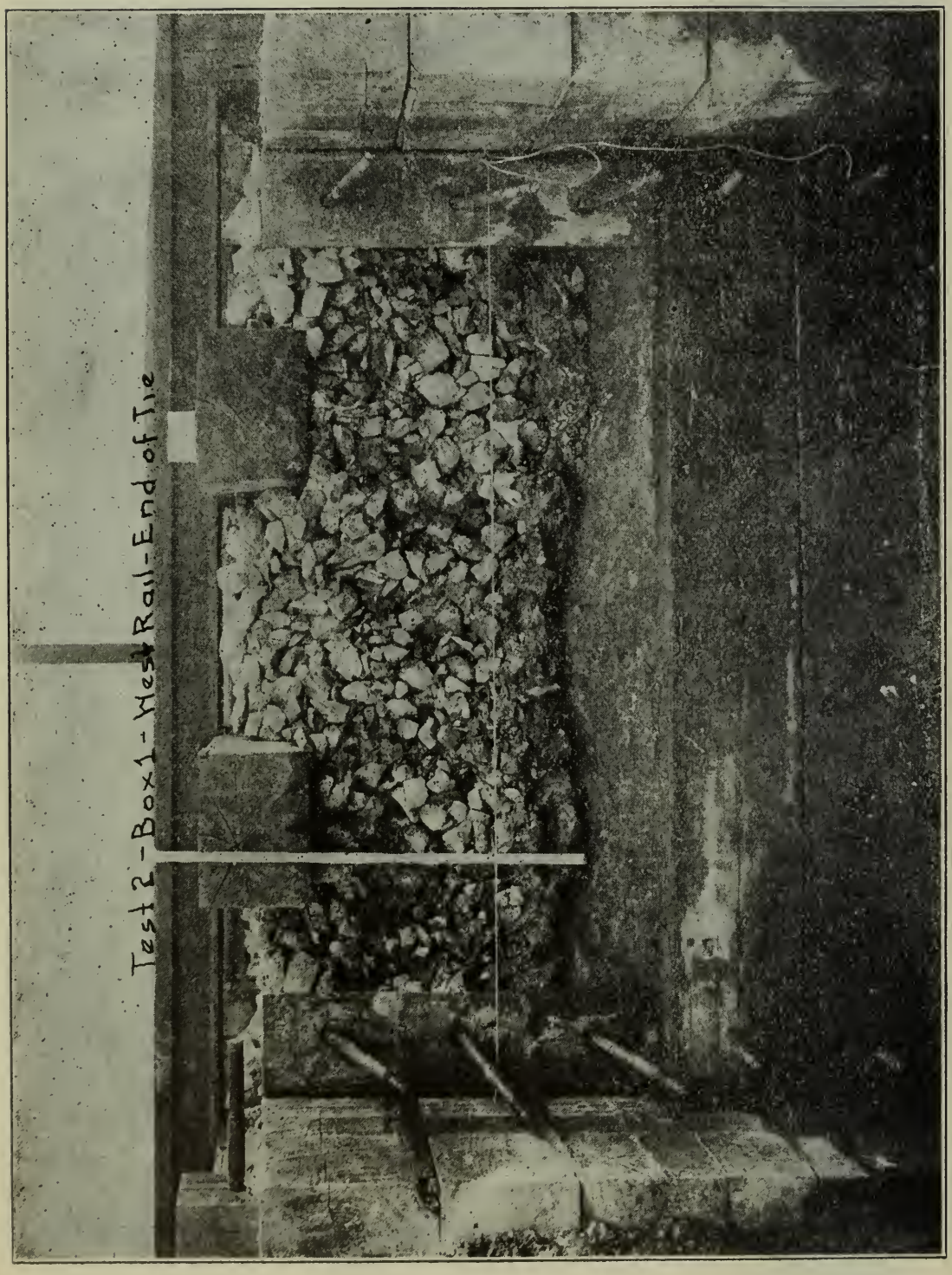
Upon opening the boxes on June 15 it was found that the loam in each box had been compressed an average of 8 in. in box No. 1, 6 in. in box No. 2, and 3¾ in. in box No. 3.

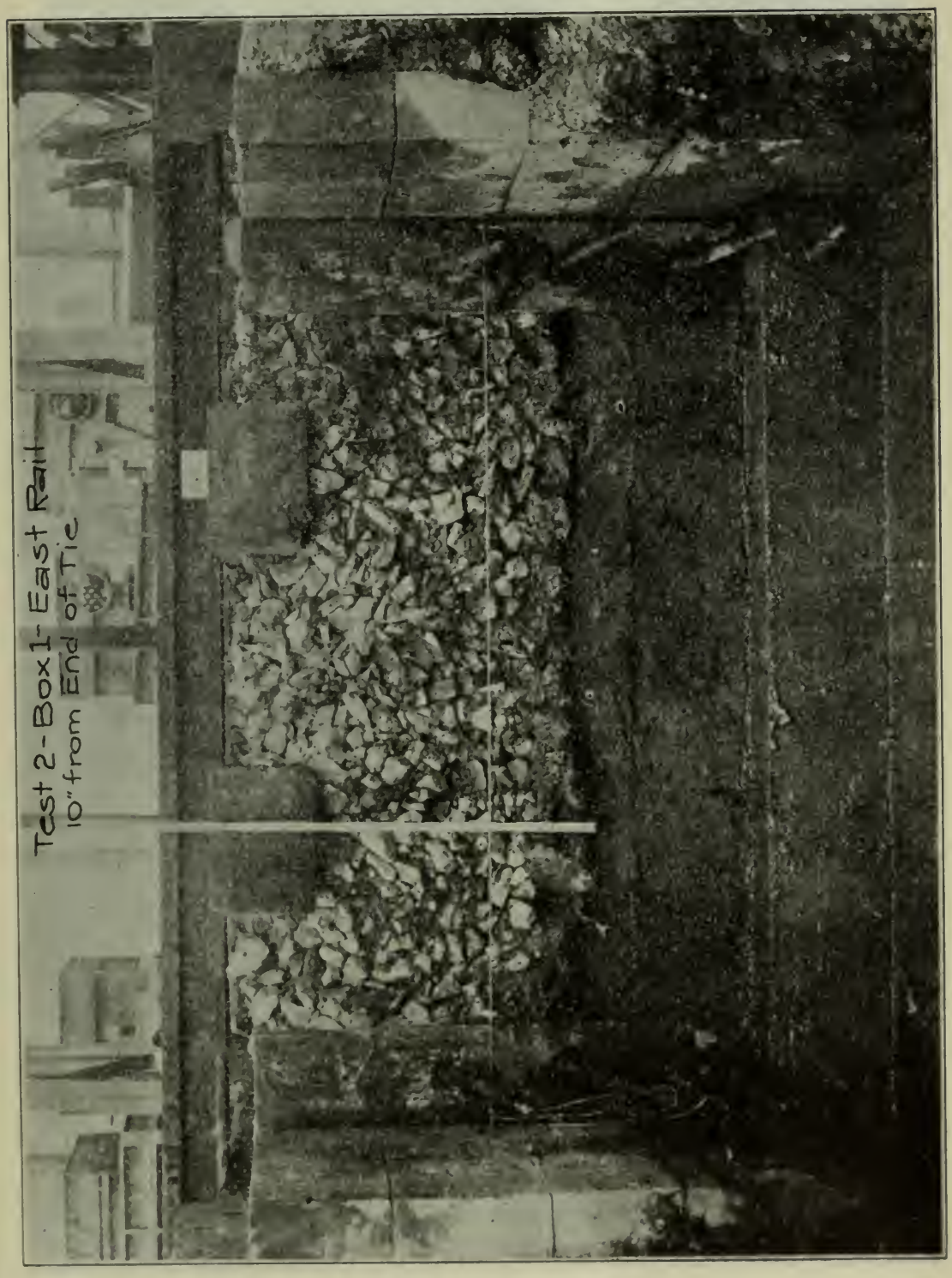
Photographs and elevations taken at the time of opening the boxes show that the loam in box No. 1 received the greatest pressure directly under the ties, thereby causing unequal settlement of the loam and the formation of hollows under the ties. This effect was noticeable in box No. 2, but to a less degree, and in box No. 3, with 24 in. of stone ballast, the pressure was so evenly distributed over the loam that only a very slight cupping effect was noticed.

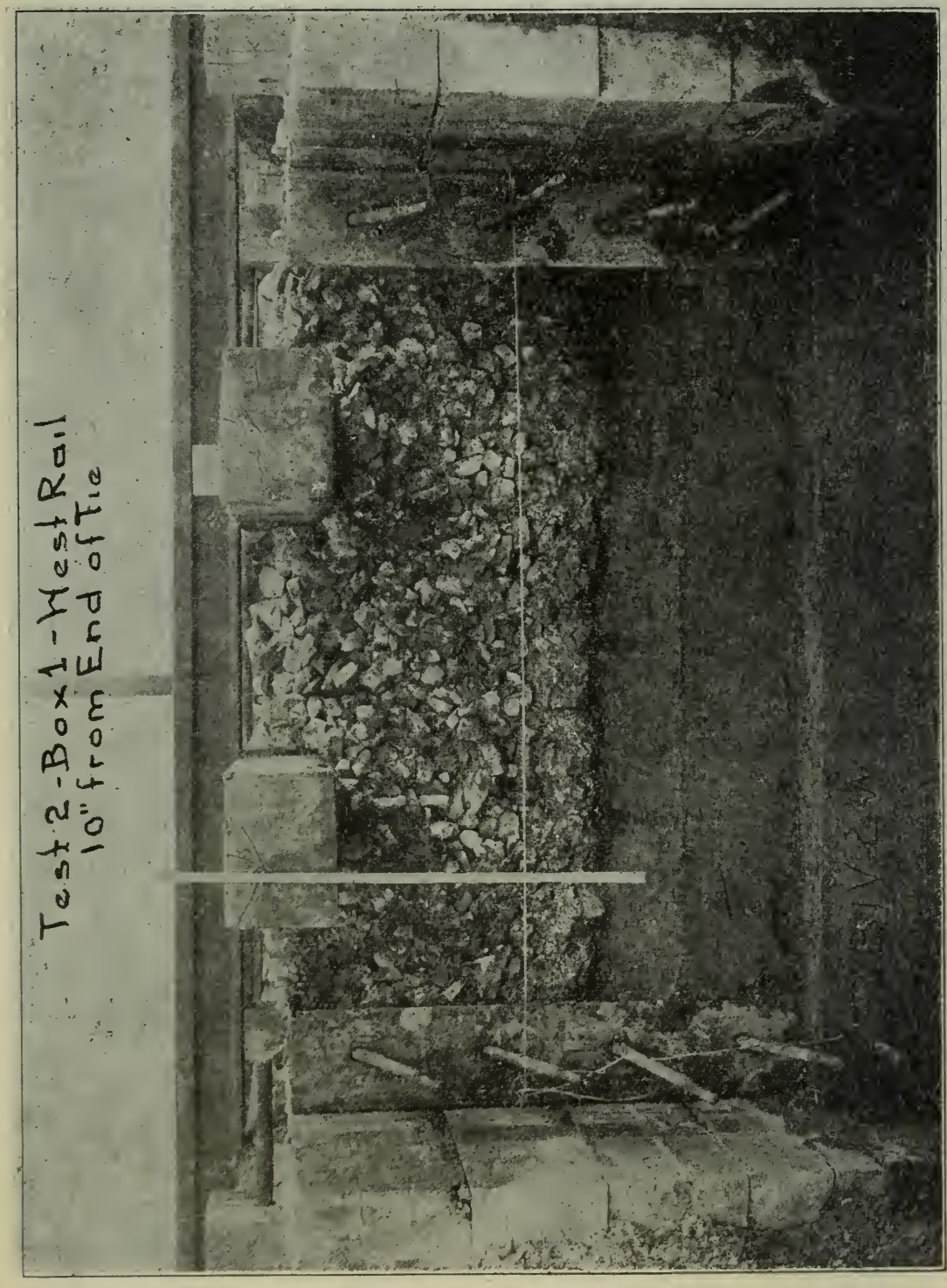
By taking elevations through the boxes at right angles to the track it was found that the greatest elevation existed along a line parallel to and equidistant from the rails. From this line the surface of the loam inclined towards the ends of the ties, with a cupping directly under the rails. Box No. 3 showed the most uniform surface of sub-grade.

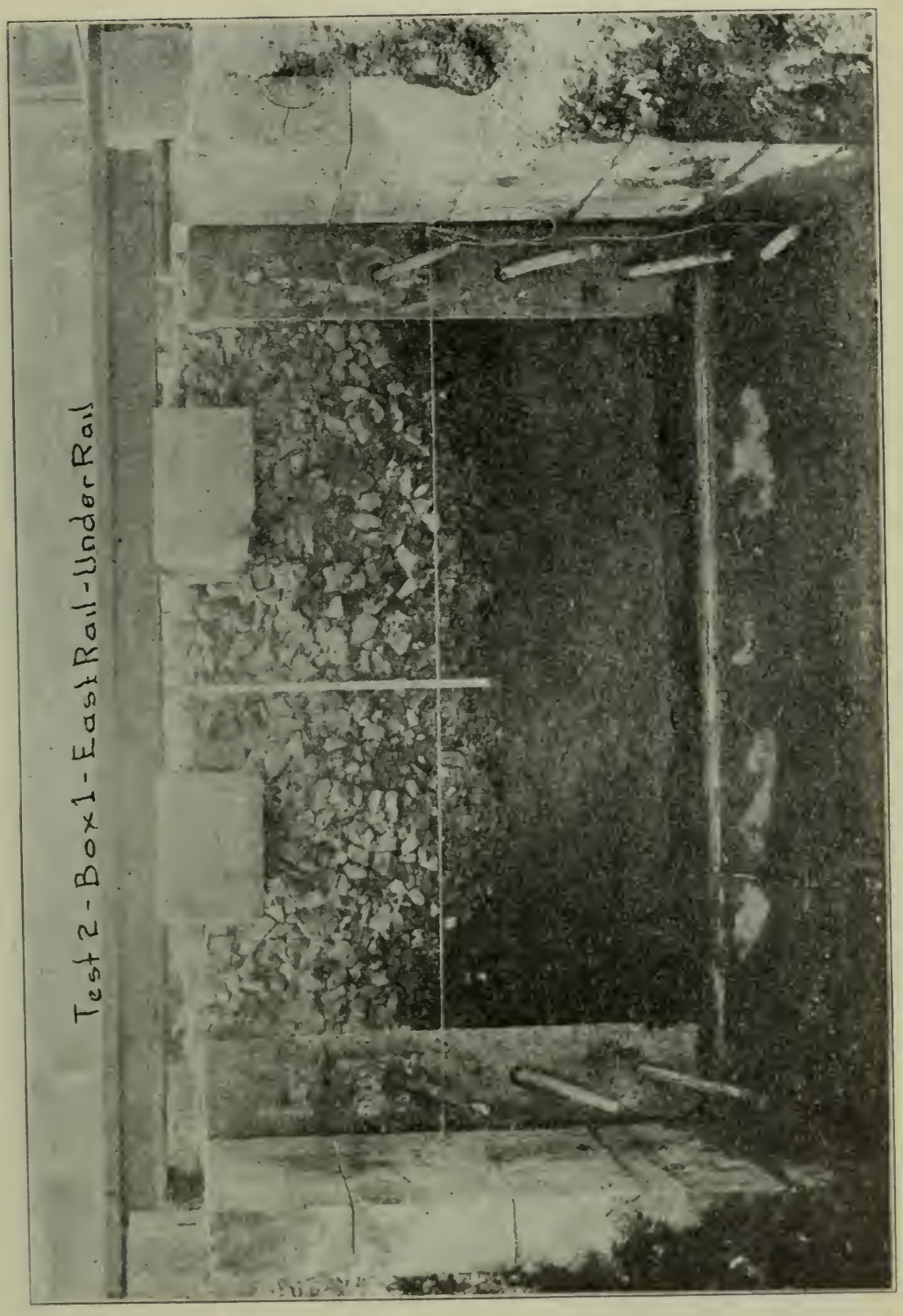
It was found that the water had not penetrated the loam to a greater depth than three or four inches and at the time of investigation trickled out over the sub-grade in small streams.

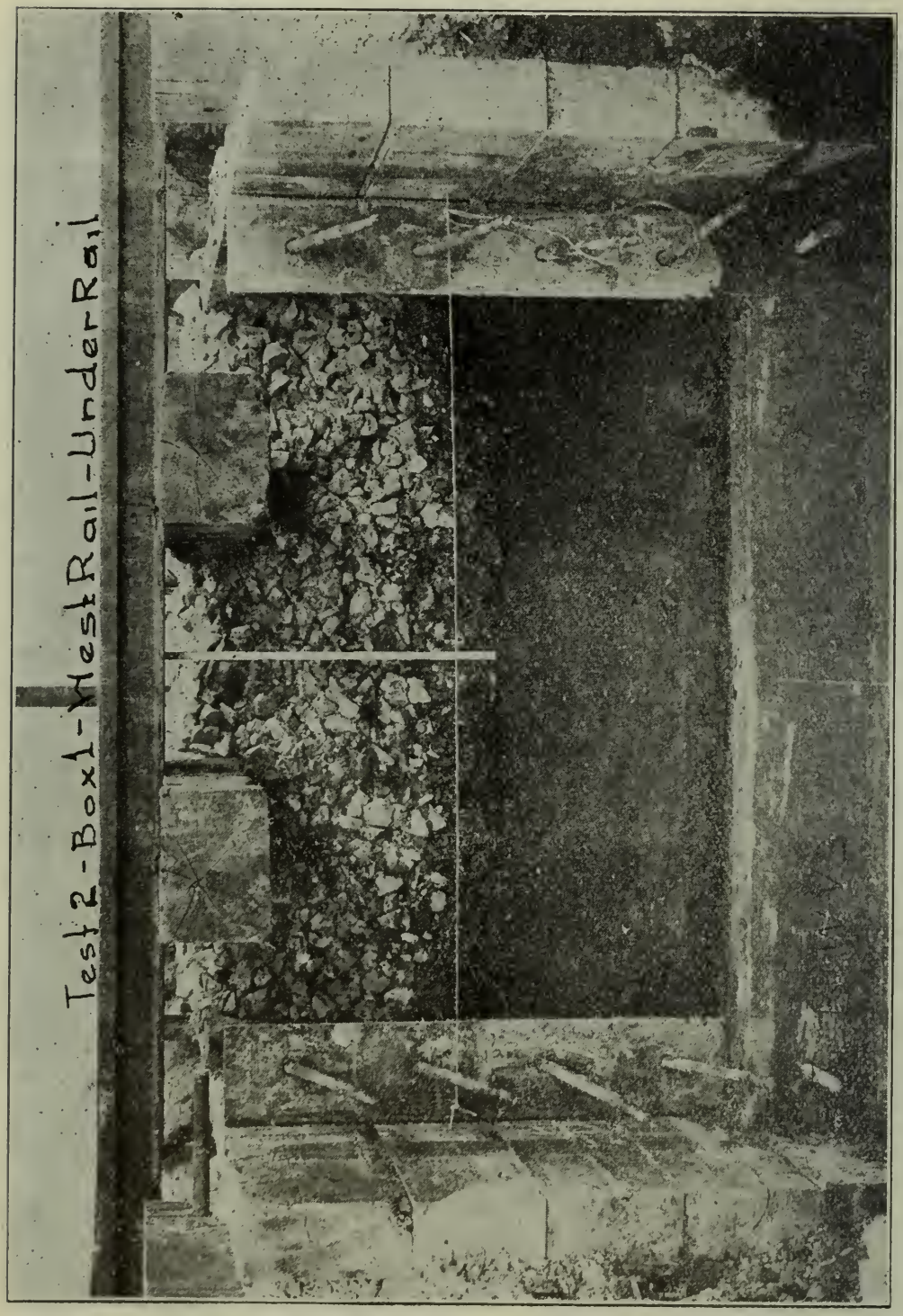

Test 2 - Box 1 - East Rail - End of Tie

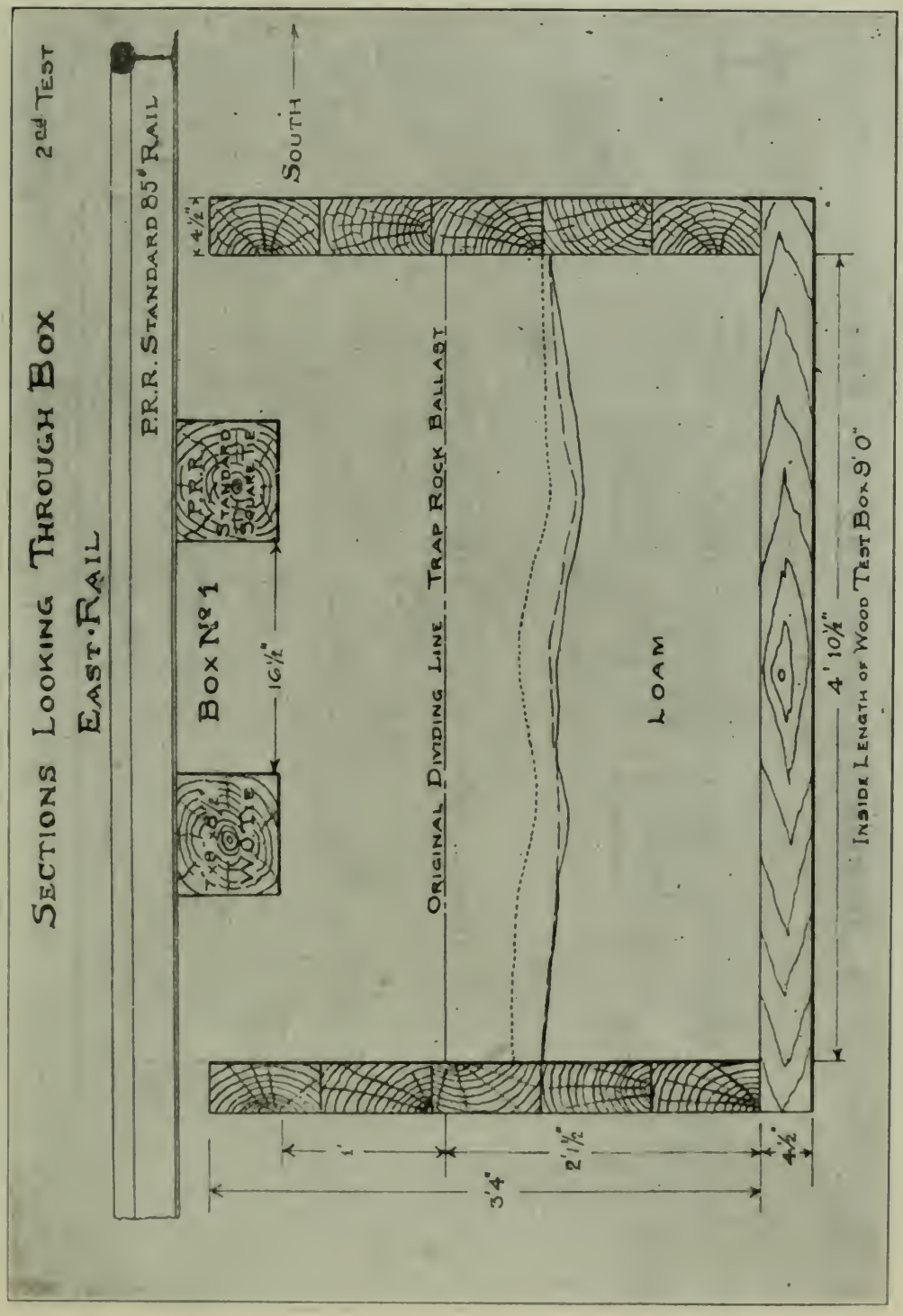

Test 2 - Box 1 - West Rail - End of Tie

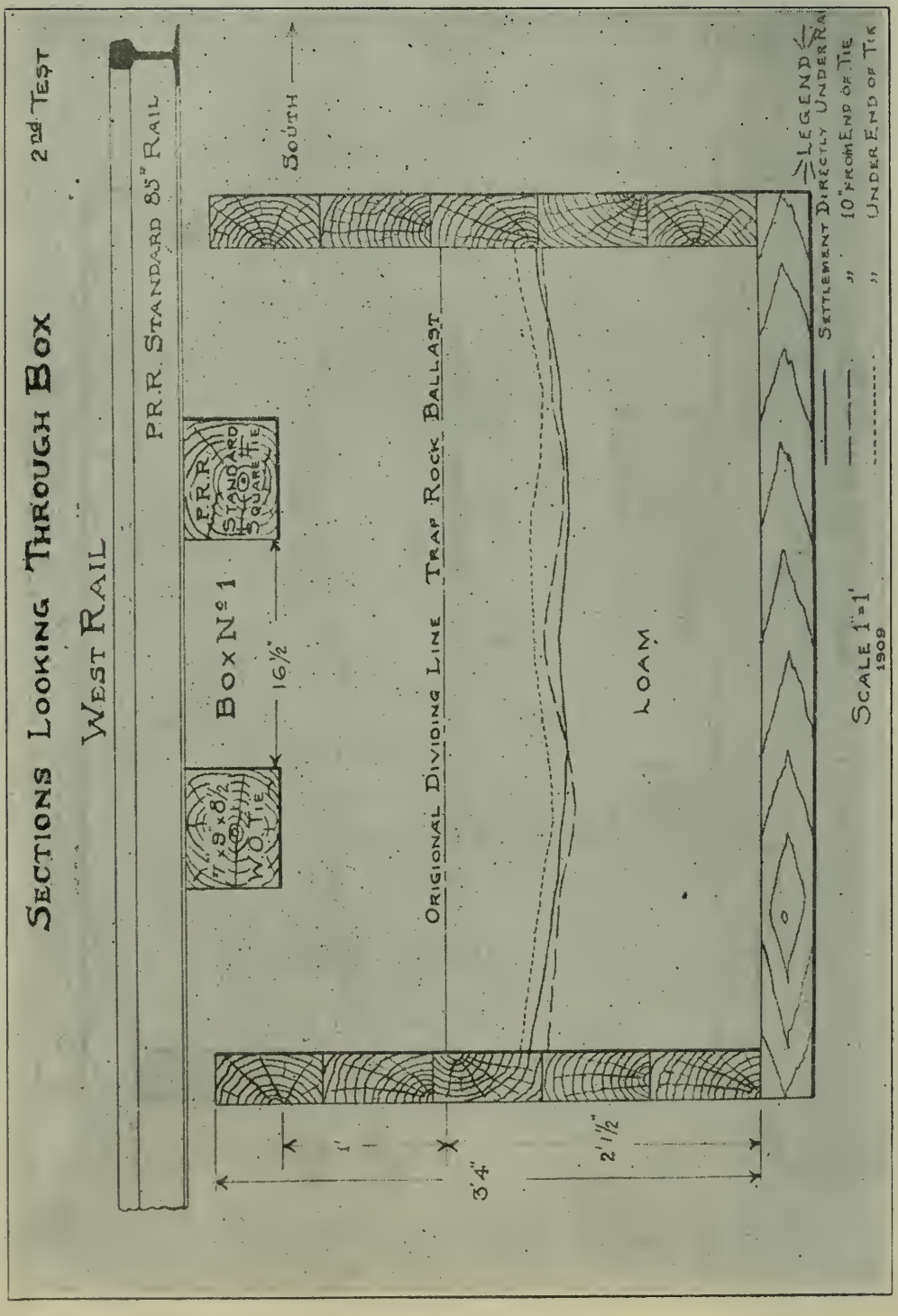

Test 2-Box 1-East Rail
10" from End of Tie

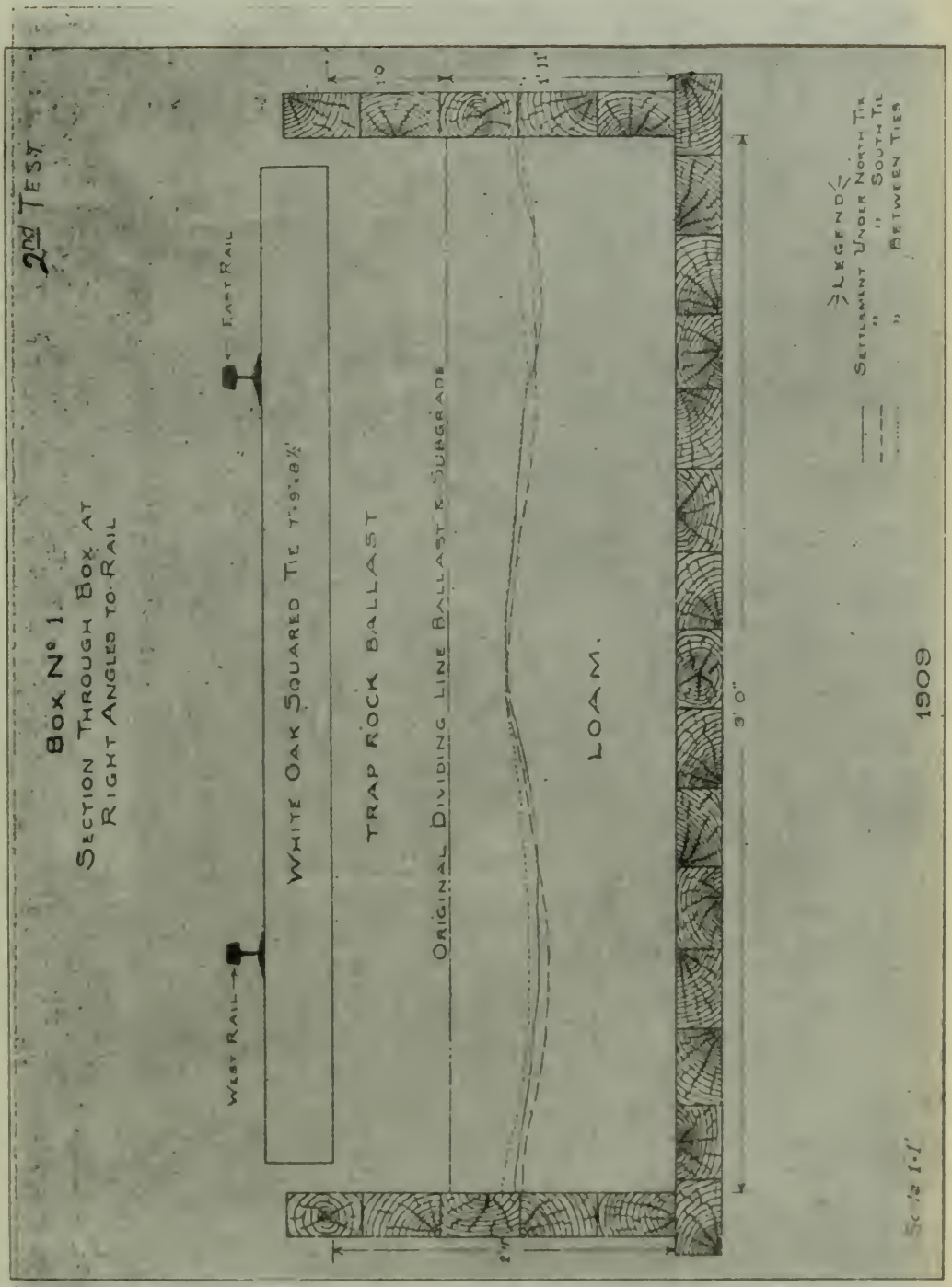

Test 2-Box 1-West Rail
10" from End of Tie

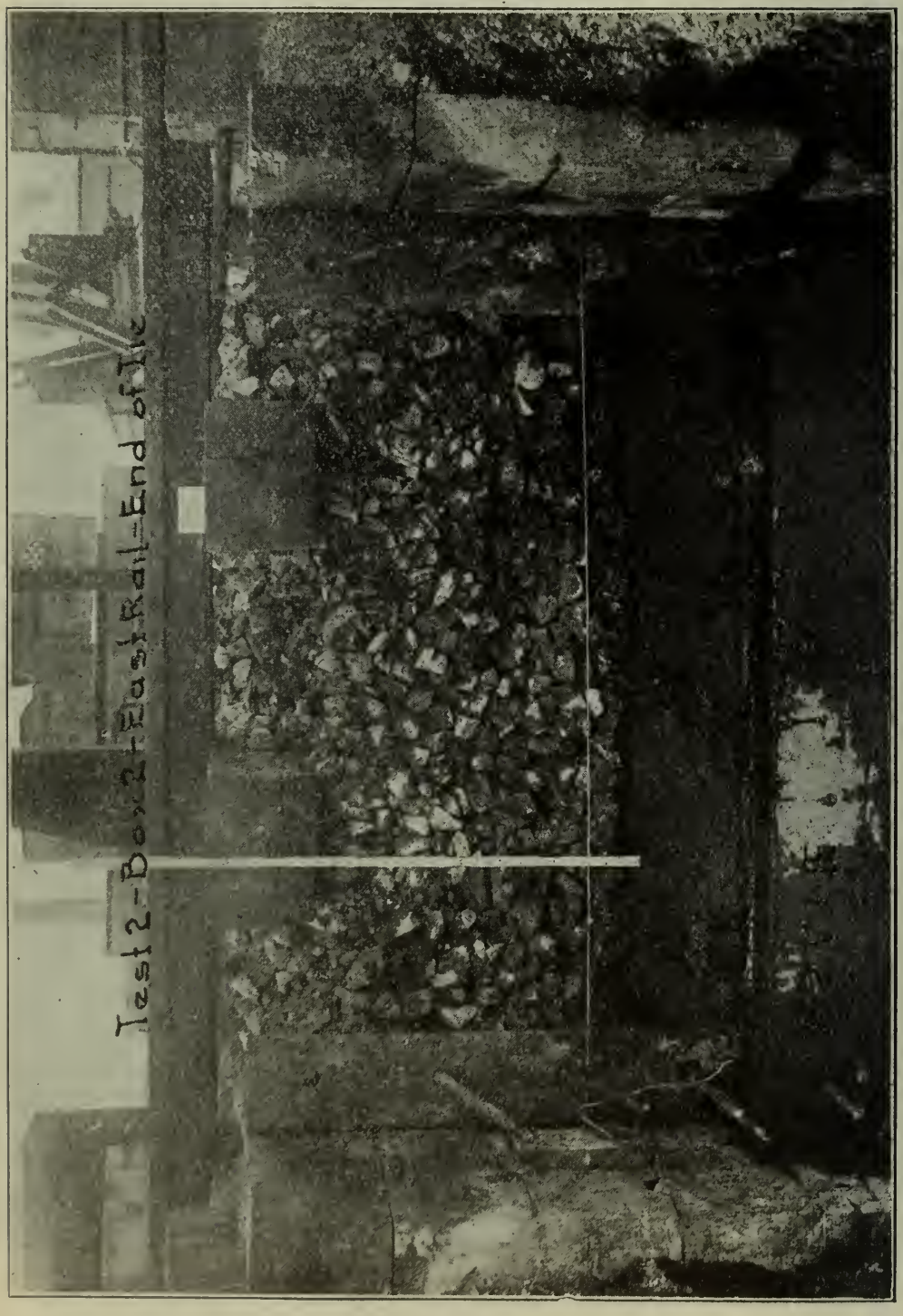

Test 2 - Box 1 - East Rail - Under Rail

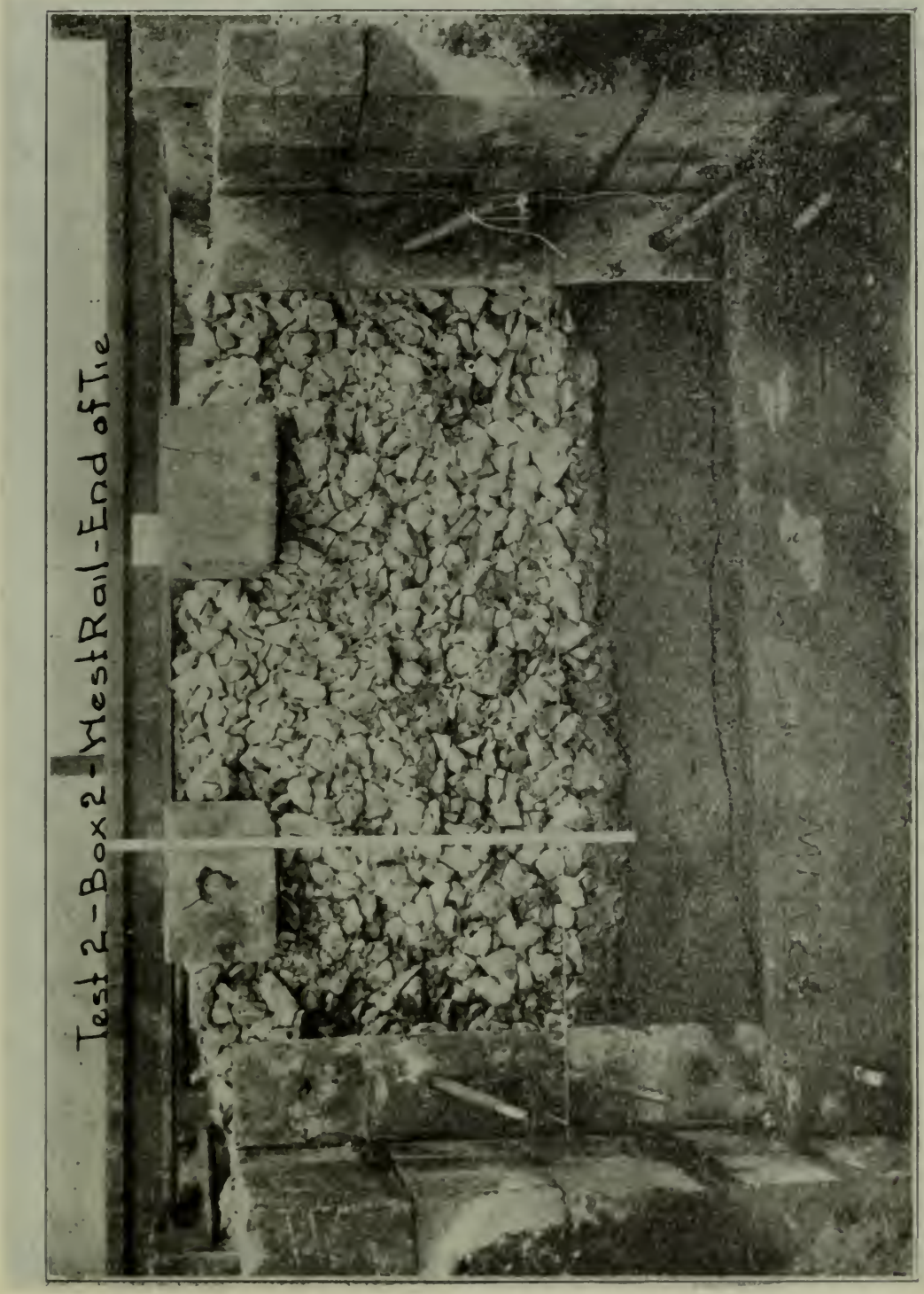

Test 2-Box 1-West Rail-Under Rail

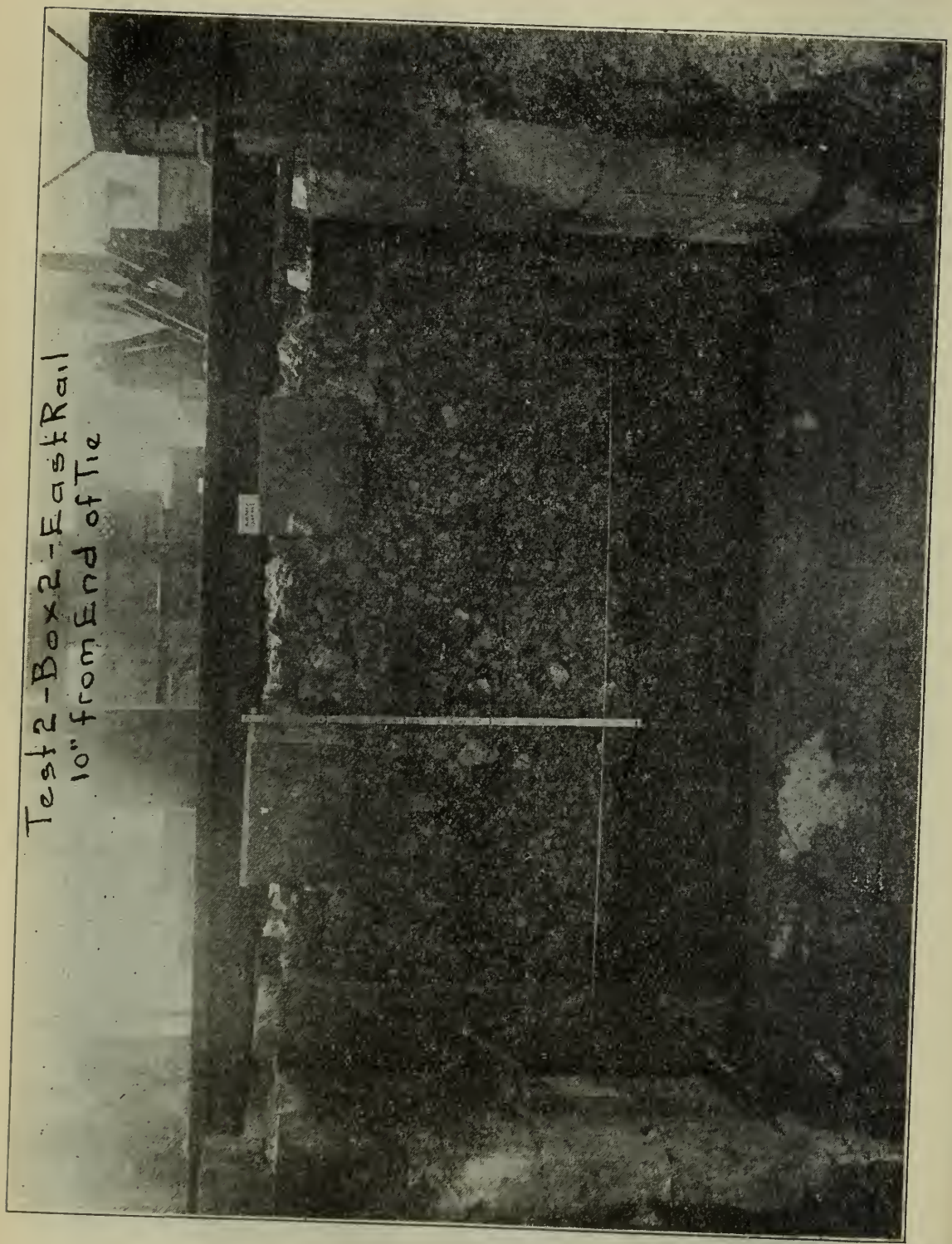

SECTIONS LOOKING THROUGH BOX
2nd TEST
EAST RAIL
P.R.R. STANDARD 85# RAIL
SOUTH
4½"
P.R.R. STANDARD SQUARE TIE
BOX Nº 1
16½"
7"x8"x8½" WHITE OAK TIE
ORIGINAL DIVIDING LINE TRAP ROCK BALLAST
LOAM
4' 10½"
INSIDE LENGTH OF WOOD TEST BOX 9' 0"
1'
2' 1½"
4½"
3'4"

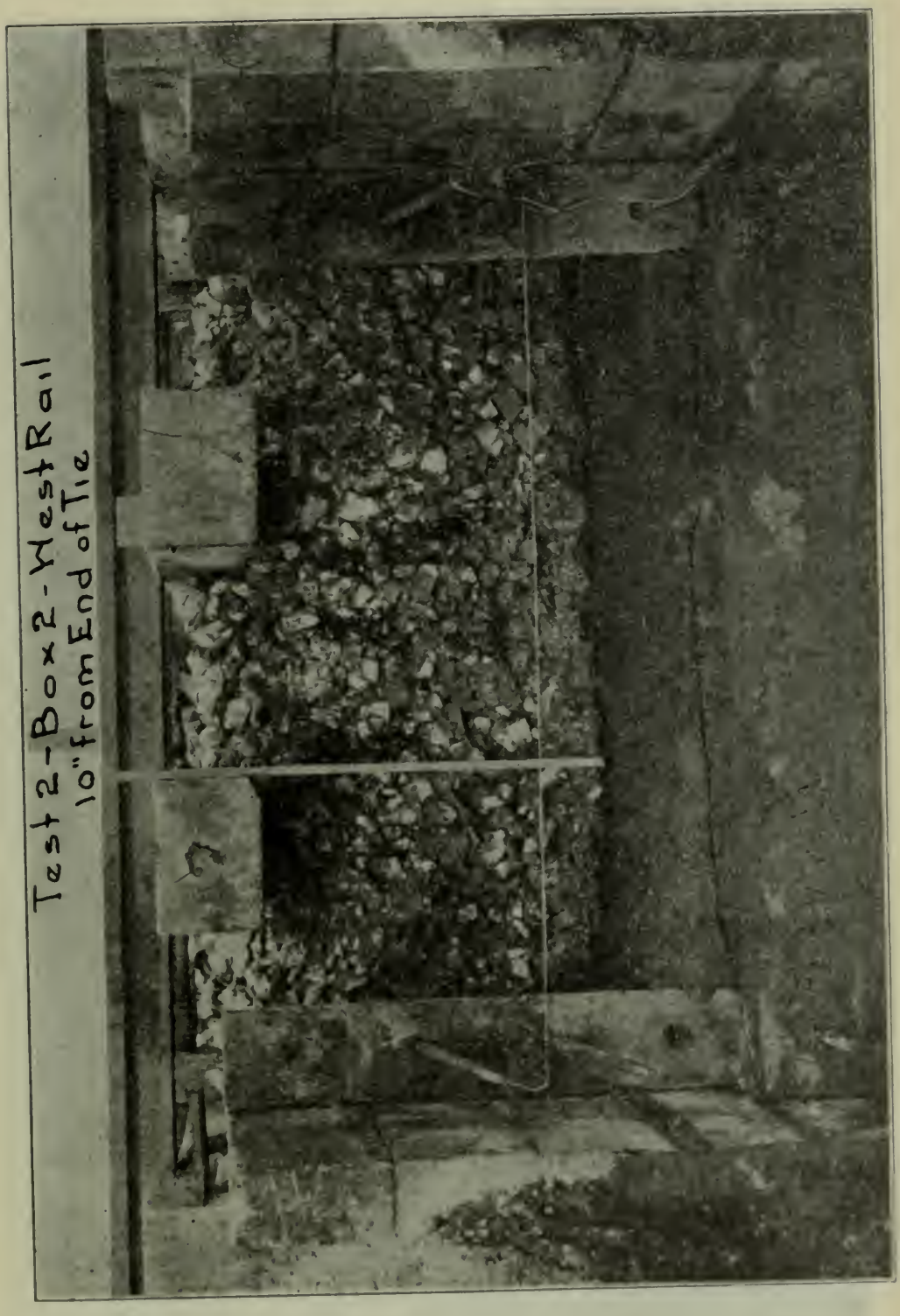

SECTIONS LOOKING THROUGH BOX
2nd TEST
WEST RAIL
P.R.R. STANDARD 85# RAIL
SOUTH
BOX Nº 1
16½"
P.R.R. STANDARD SQUARE TIE
7"x8"x8½" WOOD TIE
ORIGINAL DIVIDING LINE TRAP ROCK BALLAST
LOAM
LEGEND
SETTLEMENT DIRECTLY UNDER RAIL
" 10" FROM END OF TIE
" UNDER END OF TIE
SCALE 1"=1'
1909
1'
3'4"
2'1½"

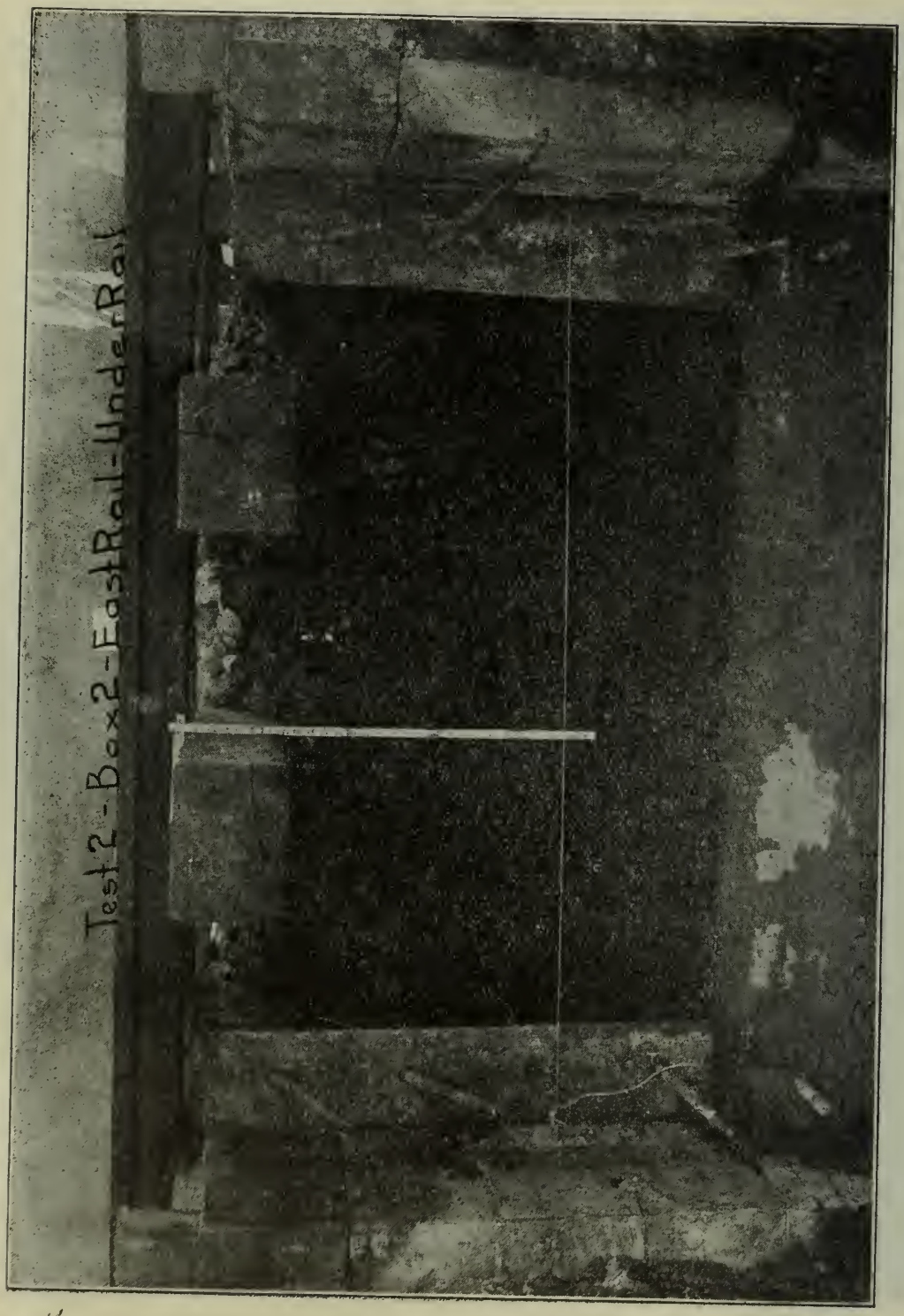

2nd Test
Box No 1.
Section Through Box at Right Angles to Rail
East Rail
West Rail
White Oak Squared Tie
Trap Rock Ballast
Original Dividing Line Ballast & Subgrade
Loam.
Legend
Settlement Under North Tie
" South Tie
" Between Ties
1909

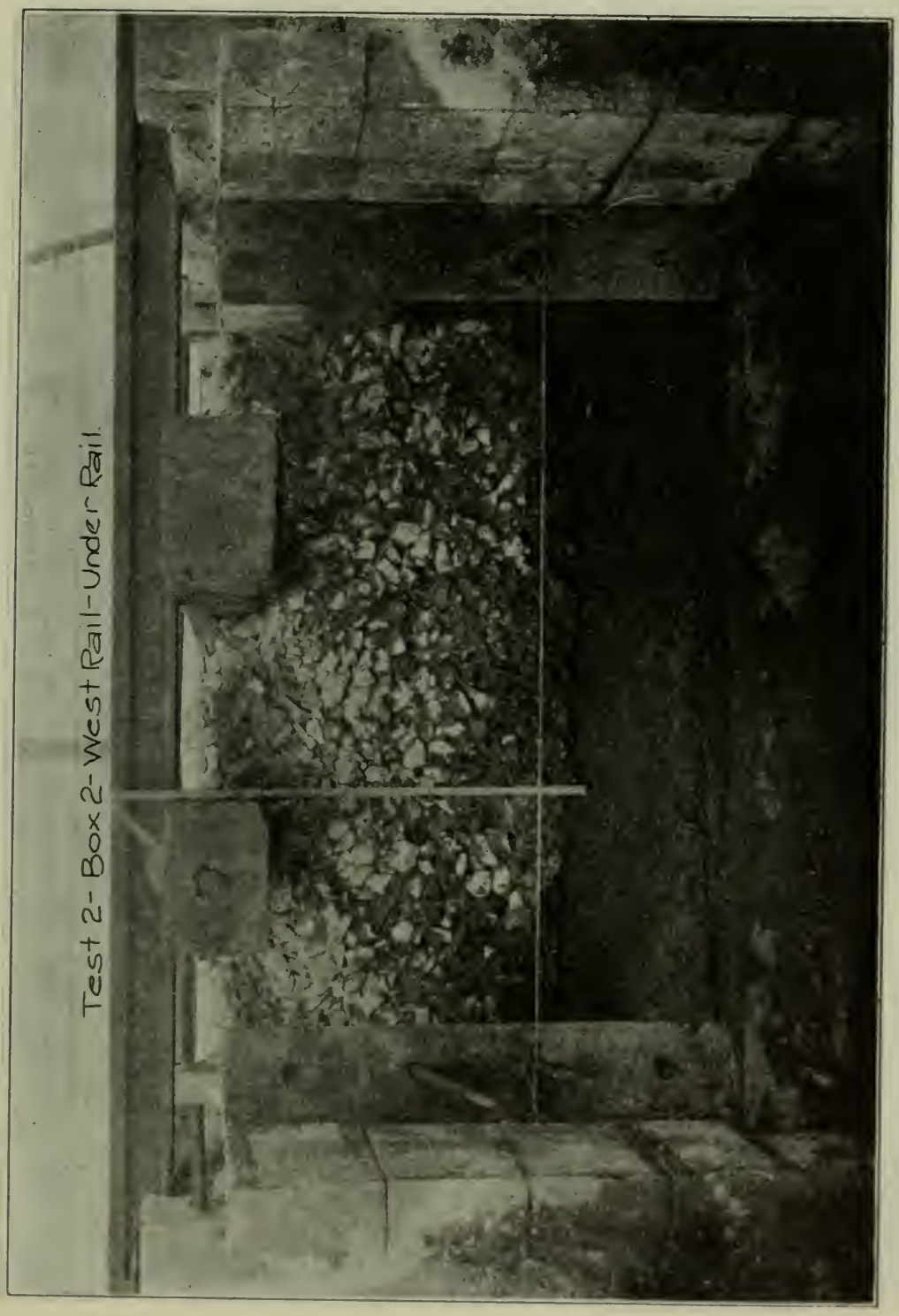

Test 2-Box 2-East Rail-End of Tie

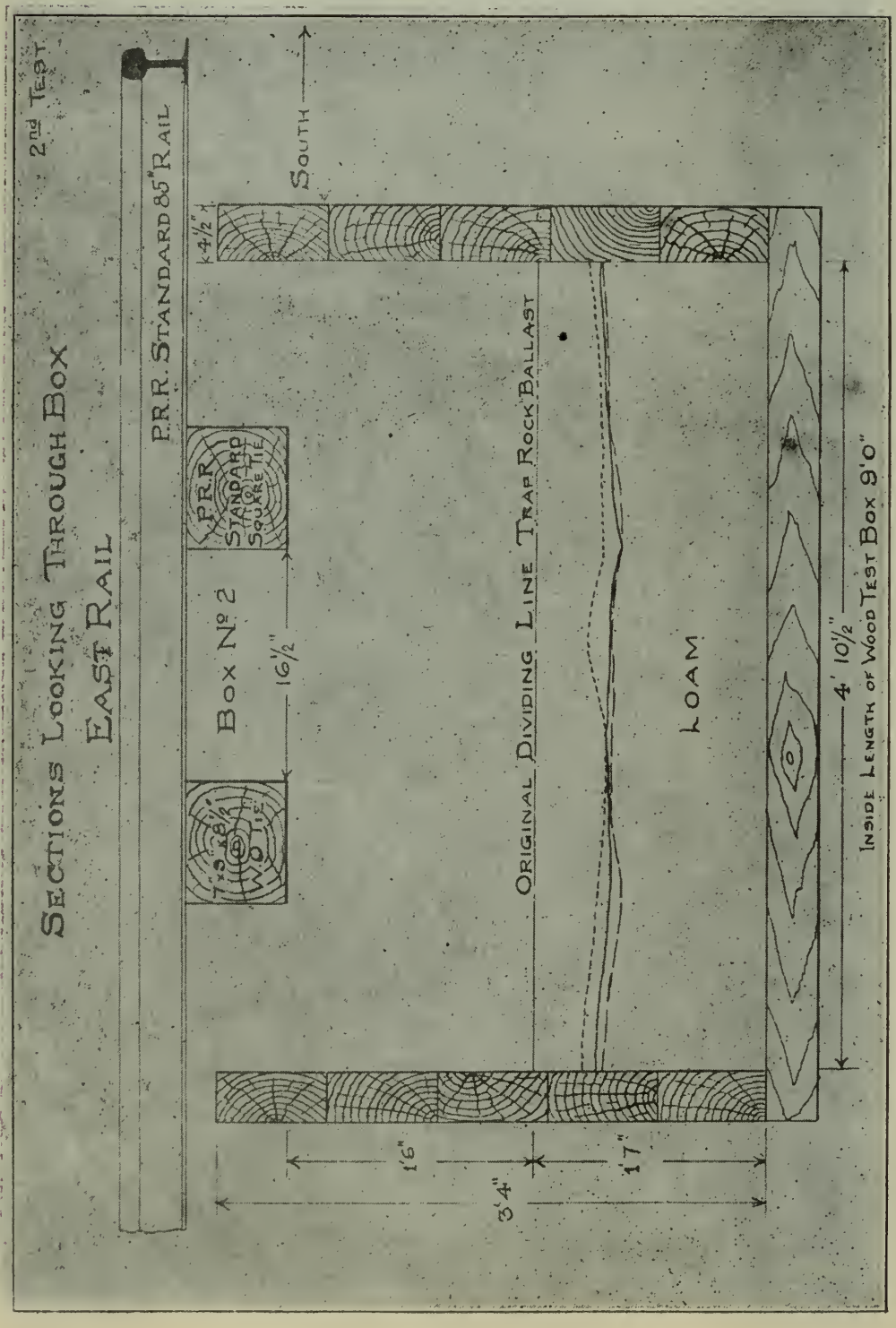

Test 2 - Box 2 - West Rail - End of Tie

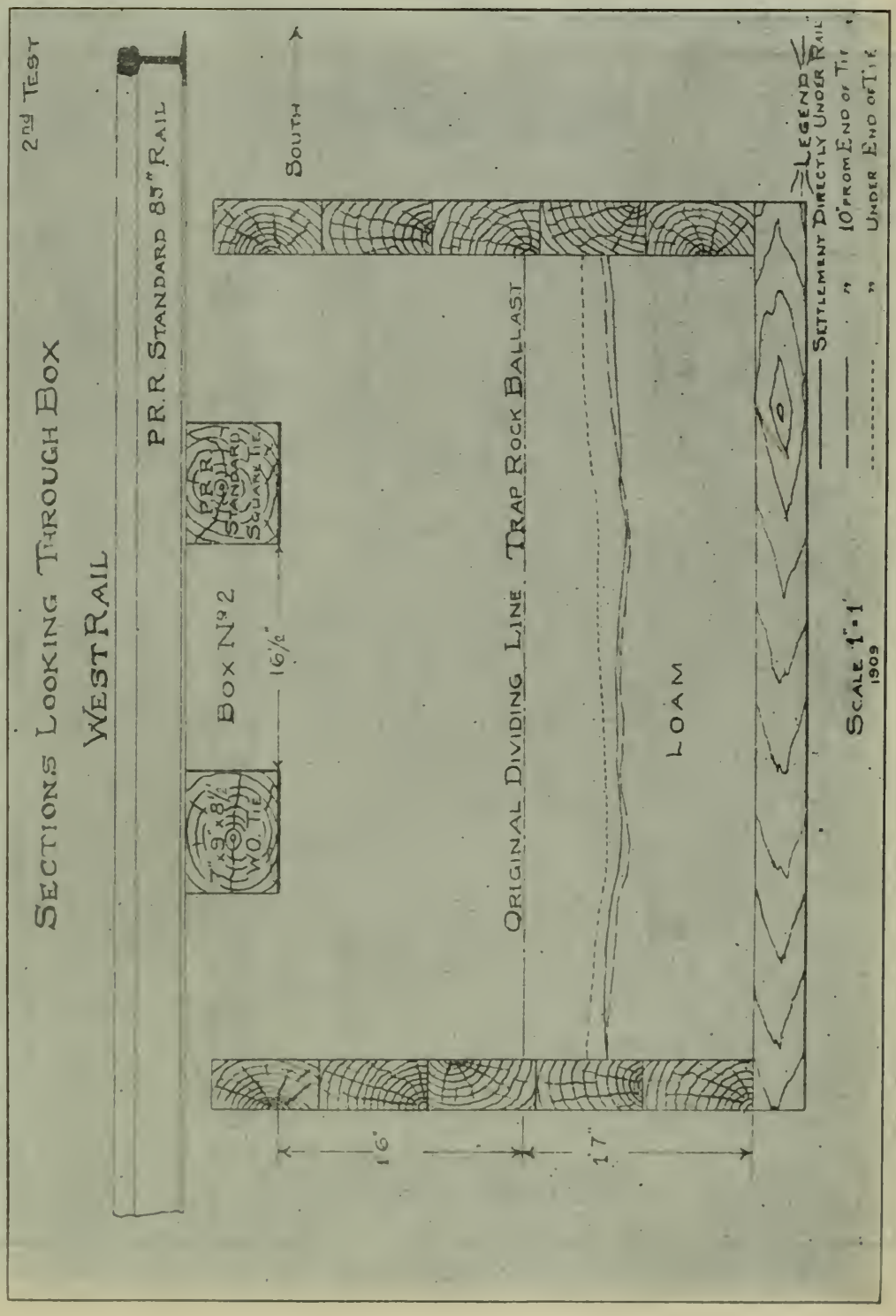

Test 2-Box 2-East Rail
10" from End of Tie

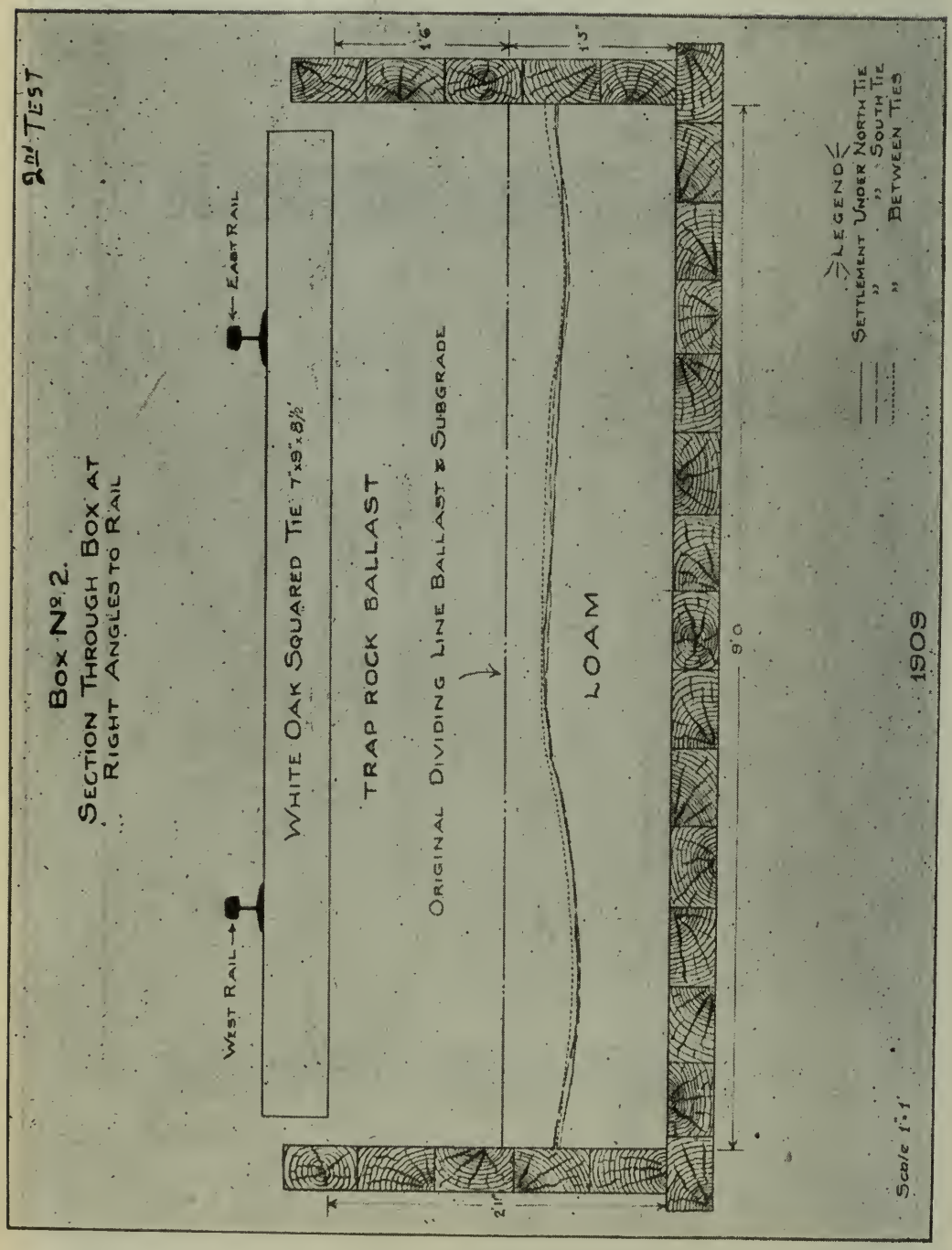

Test 2-Box 2-West Rail
10" from End of Tie

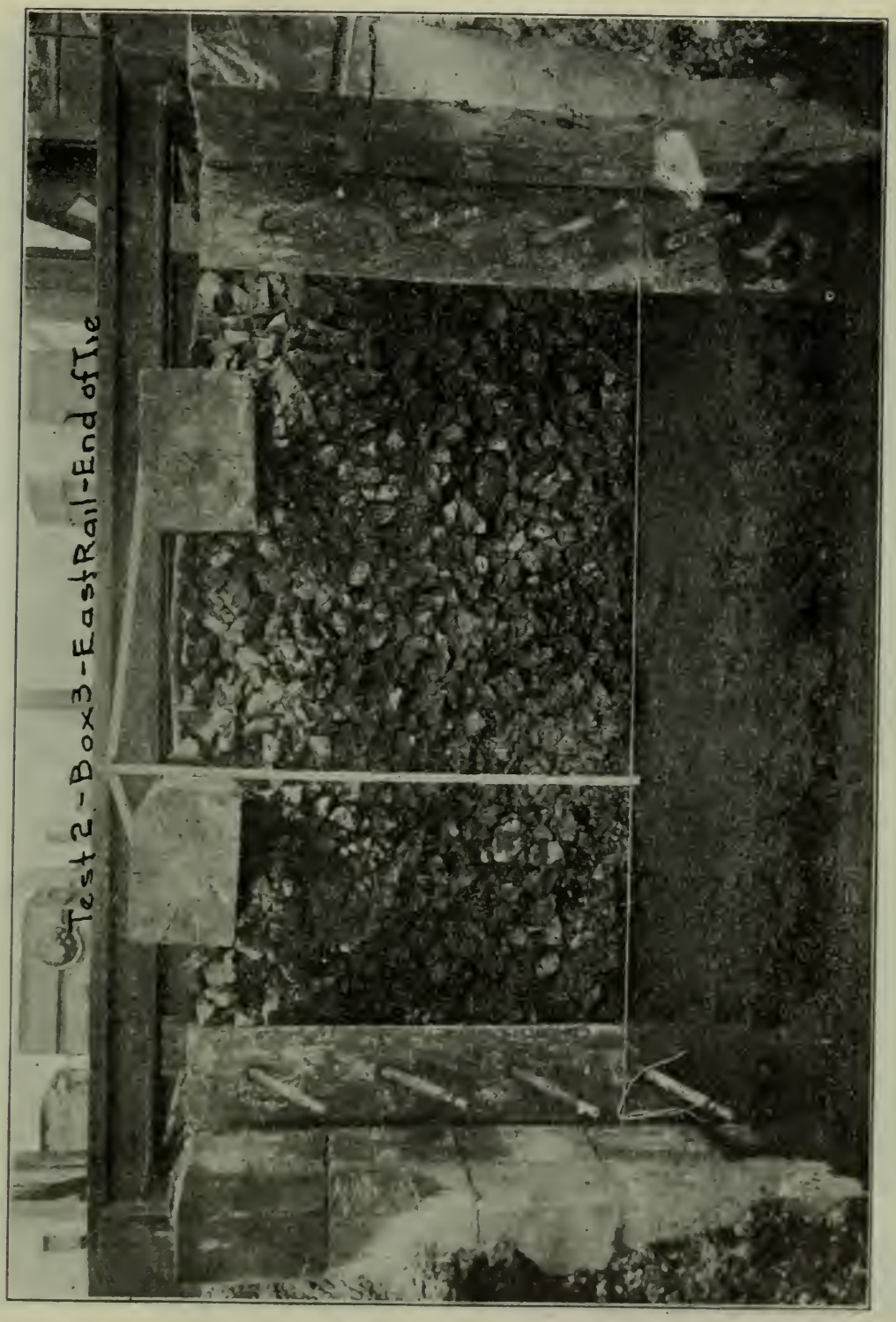

Test 2 - Box 2 - East Rail - Under Rail

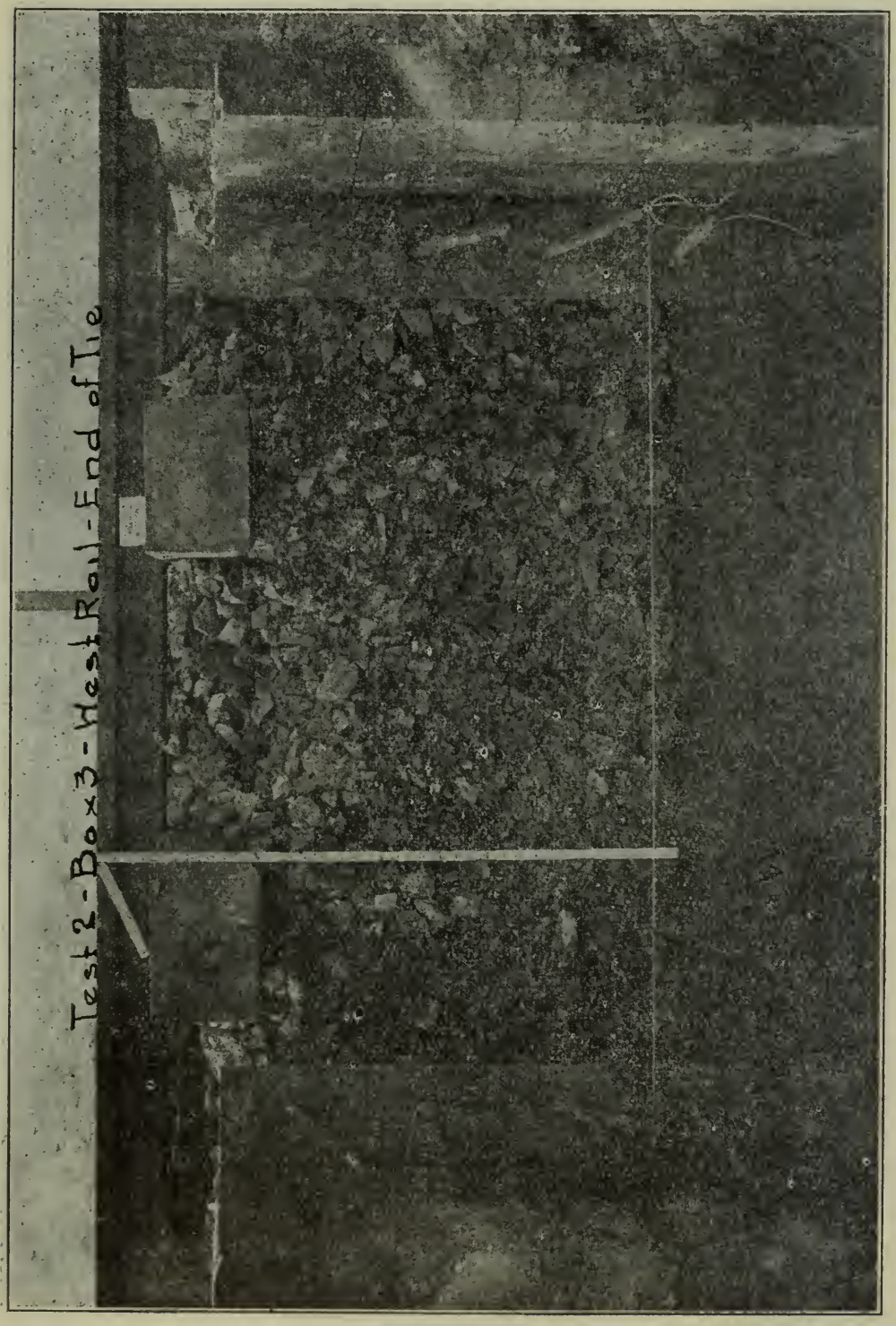

Test 2- Box 2- West Rail-Under Rail.

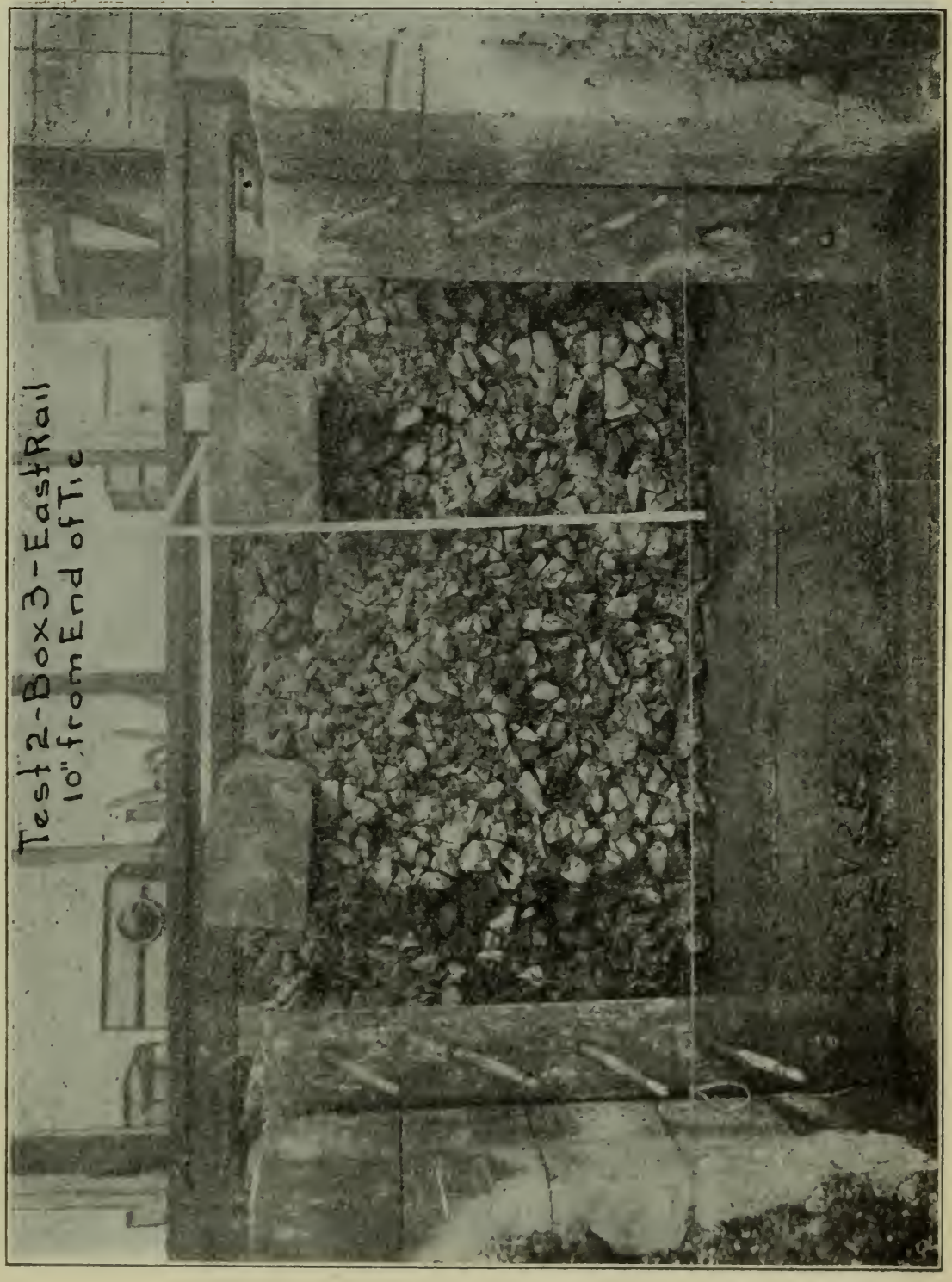

SECTIONS LOOKING THROUGH BOX
EAST RAIL
2nd TEST
P.R.R. STANDARD 85 RAIL
SOUTH
4½"
BOX Nº 2
P.R.R. STANDARD SQUARE TIE
16½"
7"x8½" WOOD TIE
ORIGINAL DIVIDING LINE TRAP ROCK BALLAST
LOAM
4' 10½"
INSIDE LENGTH OF WOOD TEST BOX 9'0"
1'6"
1'7"
3'4"

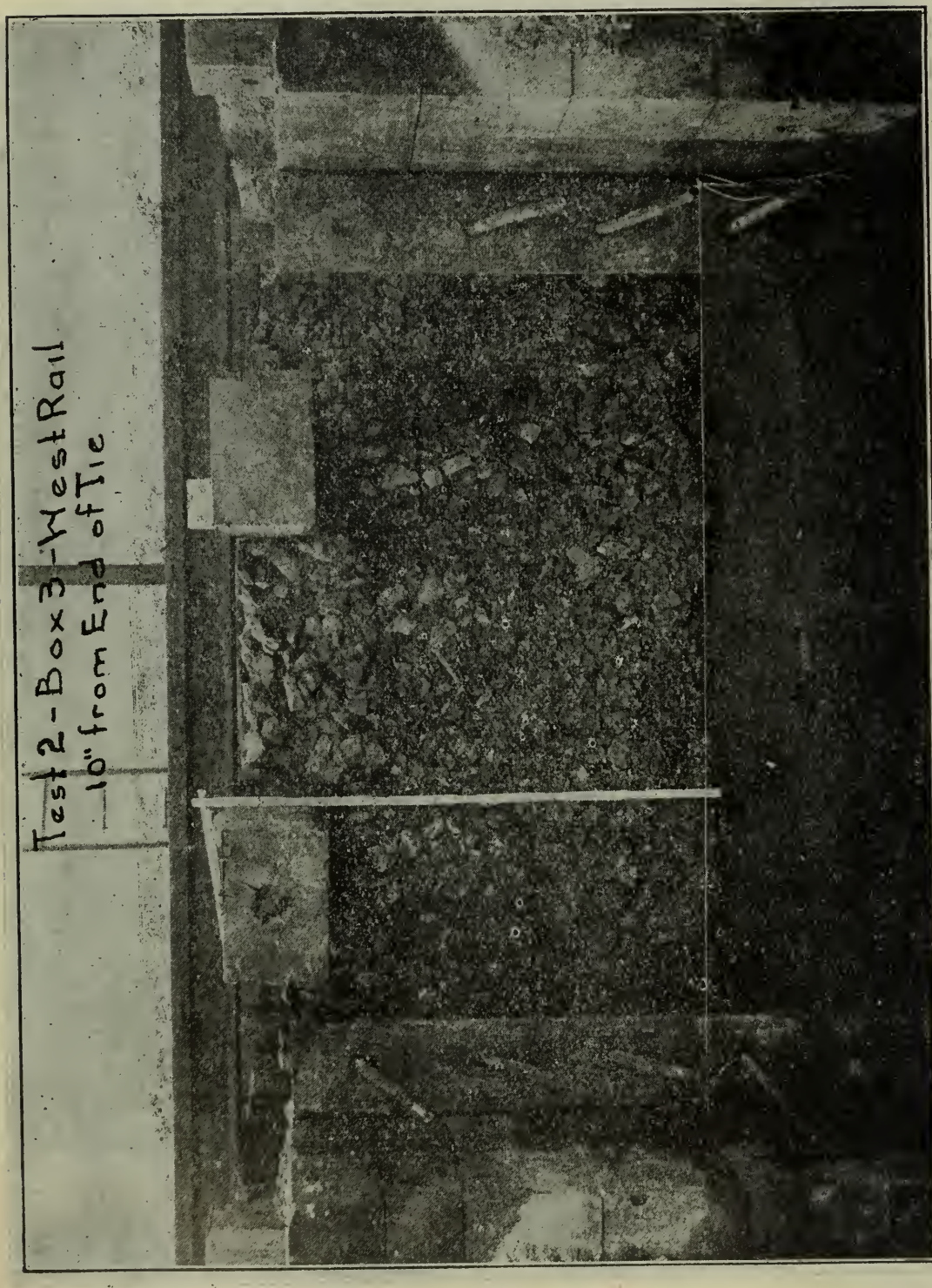

SECTIONS LOOKING THROUGH BOX
2nd TEST
WEST RAIL
P.R.R. STANDARD 85" RAIL
SOUTH
BOX Nº 2
16½"
P.R.R. STANDARD SLANT TIE
7"x9"x8½" WO TIE
ORIGINAL DIVIDING LINE
TRAP ROCK BALLAST
LOAM
16"
17"
SCALE 1"=1'
1909
LEGEND
SETTLEMENT DIRECTLY UNDER RAIL
" 10" FROM END OF TIE
" UNDER END OF TIE

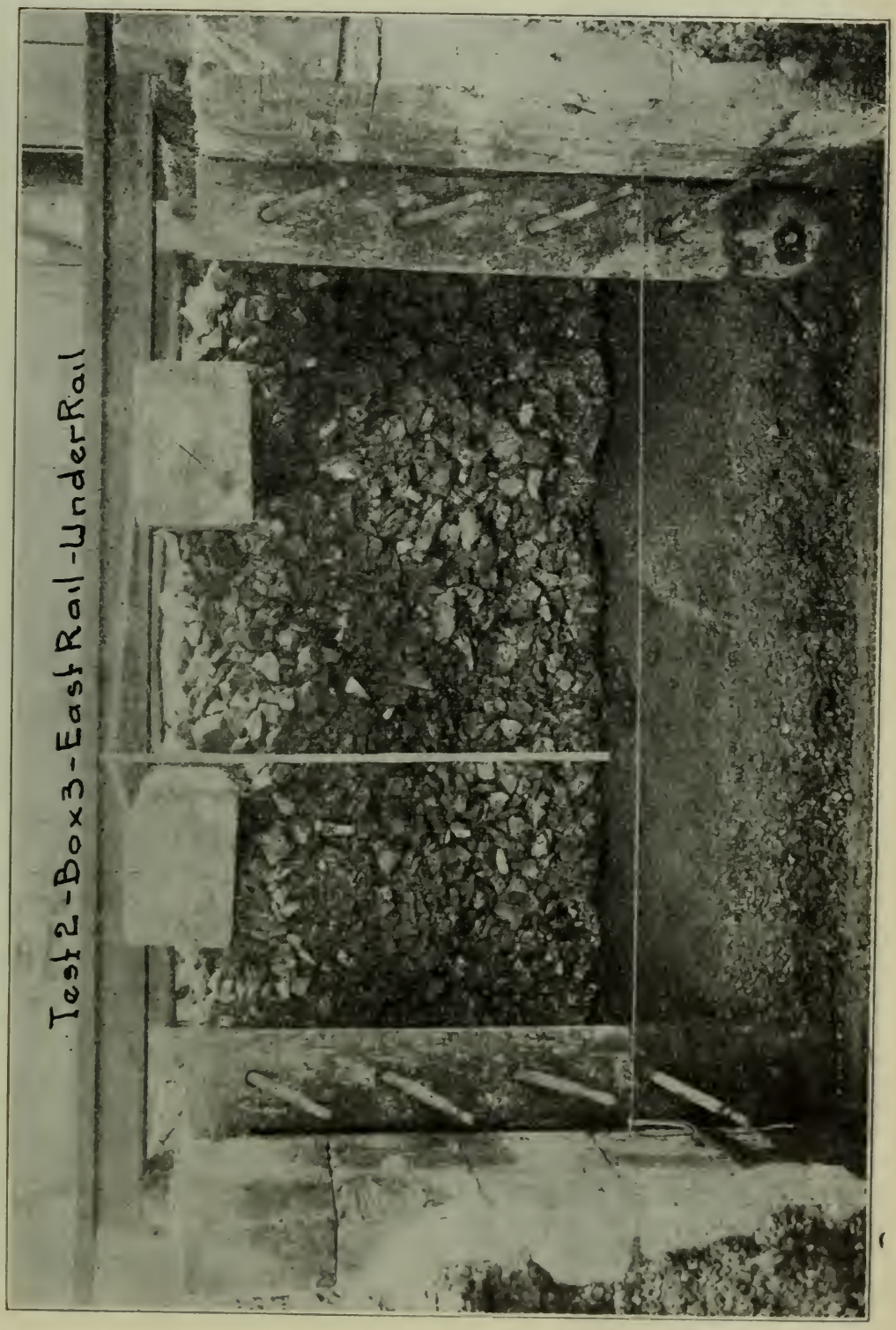

2nd Test
Box No. 2.
Section Through Box at Right Angles to Rail
East Rail
West Rail
White Oak Squared Tie 7"x9"x8½'
Trap Rock Ballast
Original Dividing Line Ballast & Subgrade
Loam
1'6"
1'3"
2'1"
9'0
Legend
Settlement Under North Tie
" " South Tie
" Between Ties
1909
Scale 1:1'

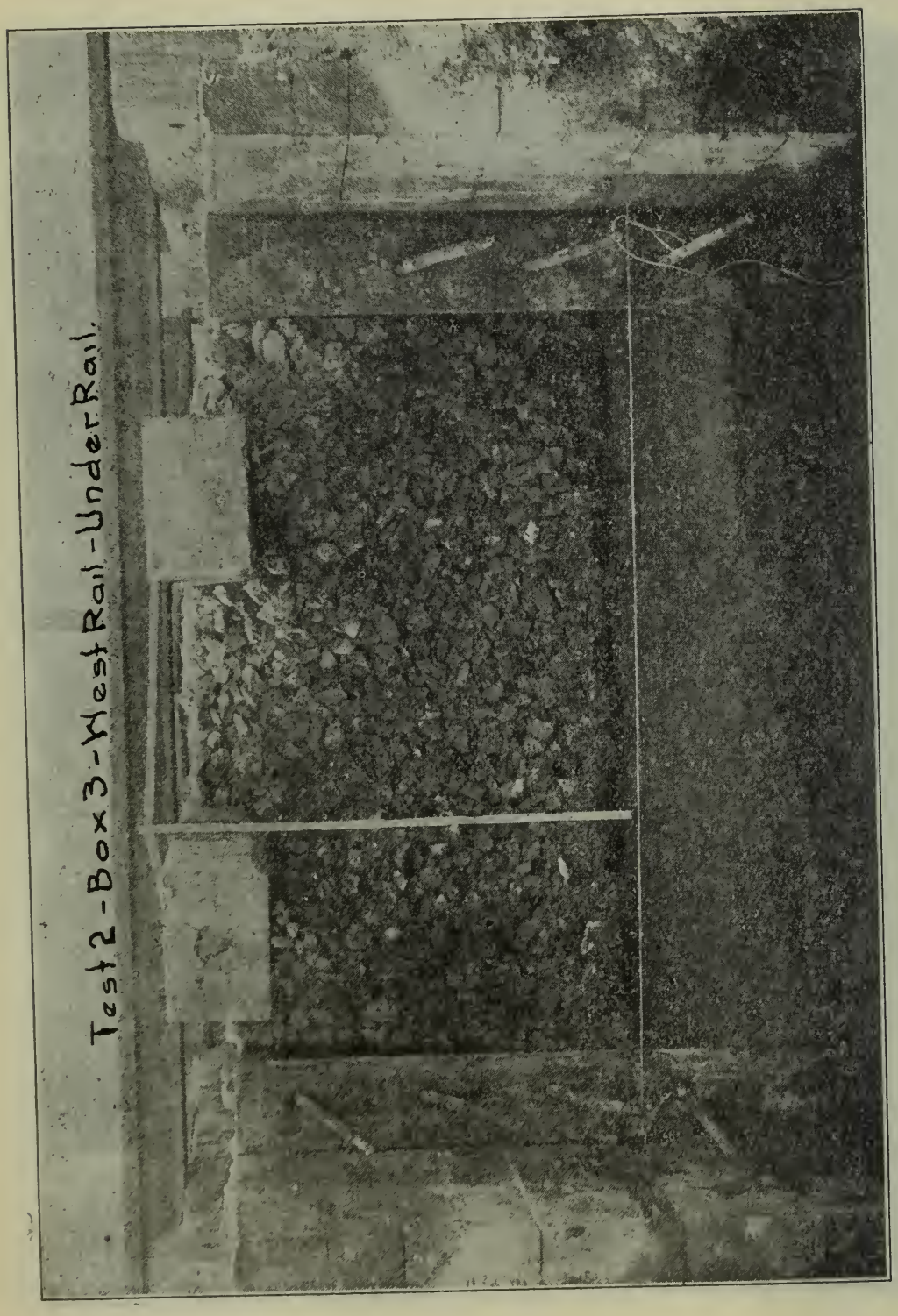

Test 2 - Box 3 - East Rail - End of Tie

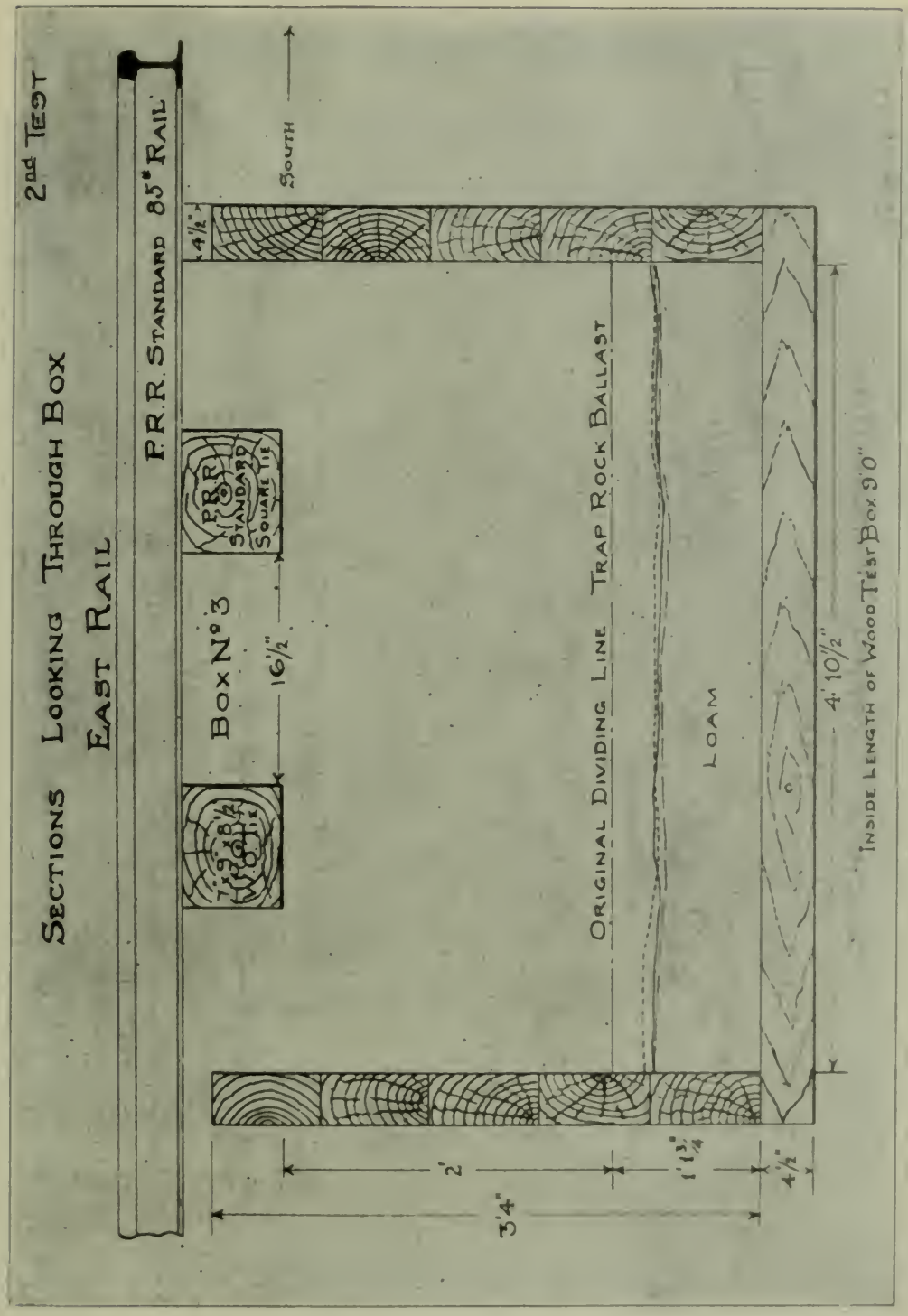

Test 2 - Box 3 - West Rail - End of Tie

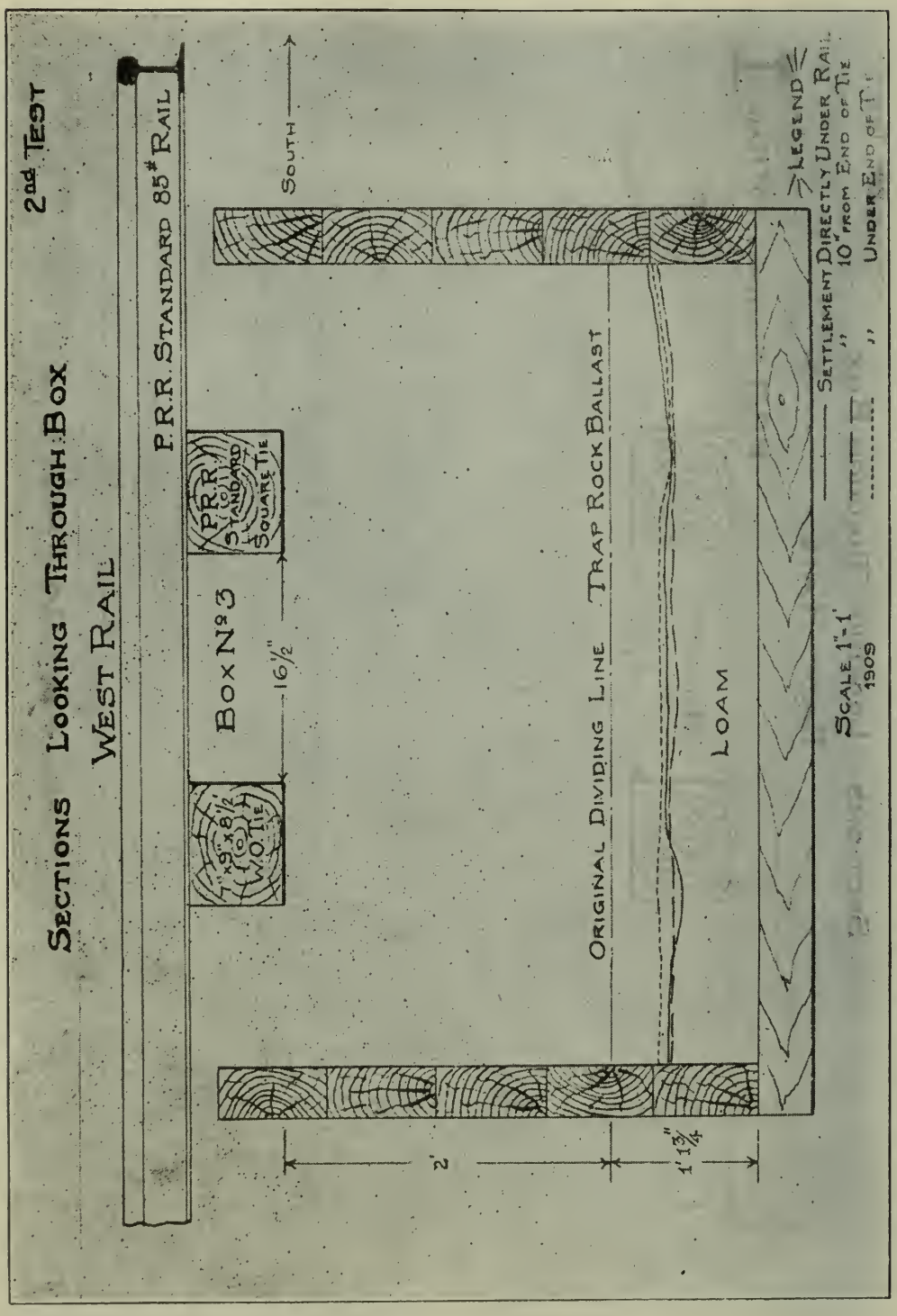

Test 2-Box 3-East Rail
10" from End of Tie

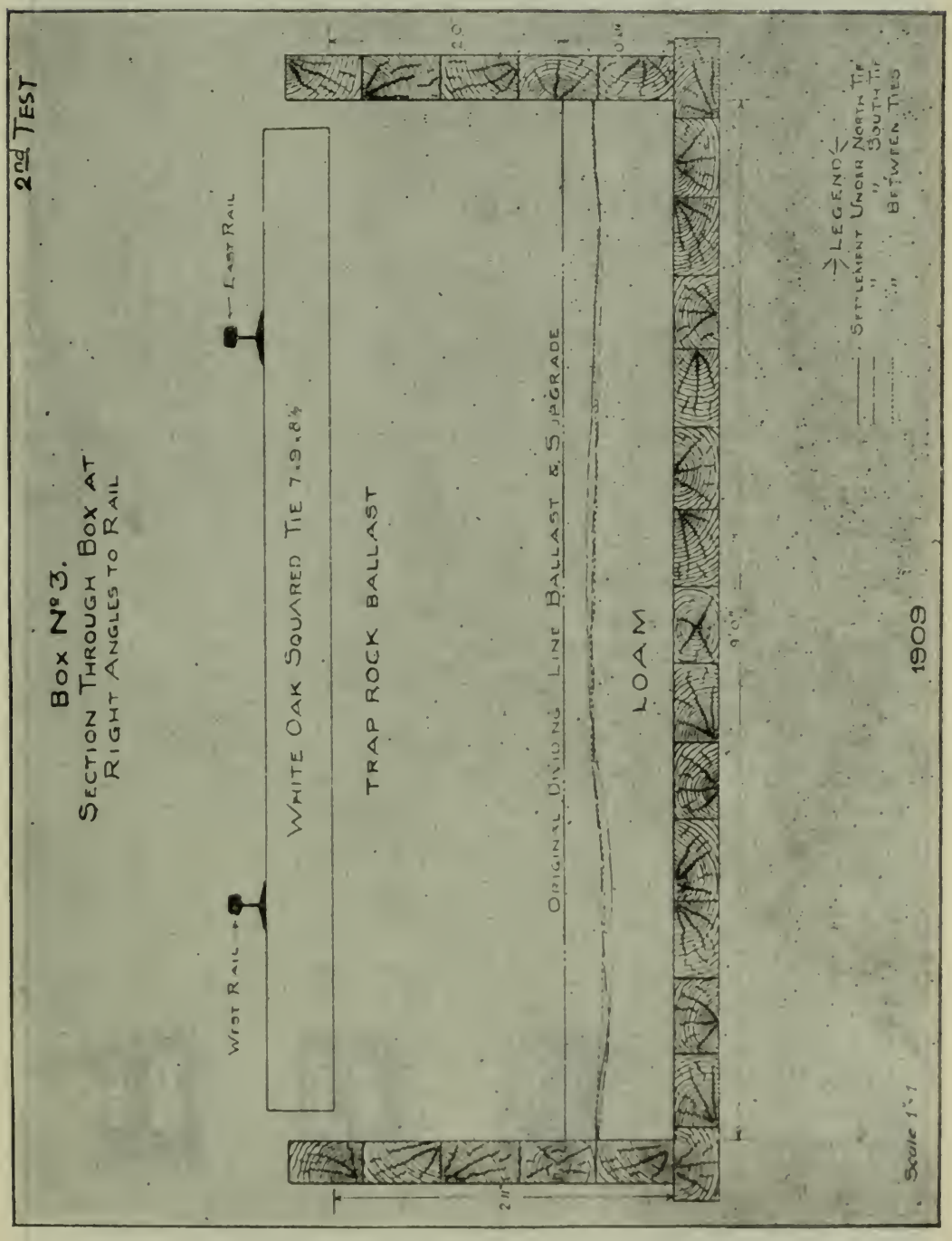

Test 2 - Box 3 - West Rail
10" from End of Tie

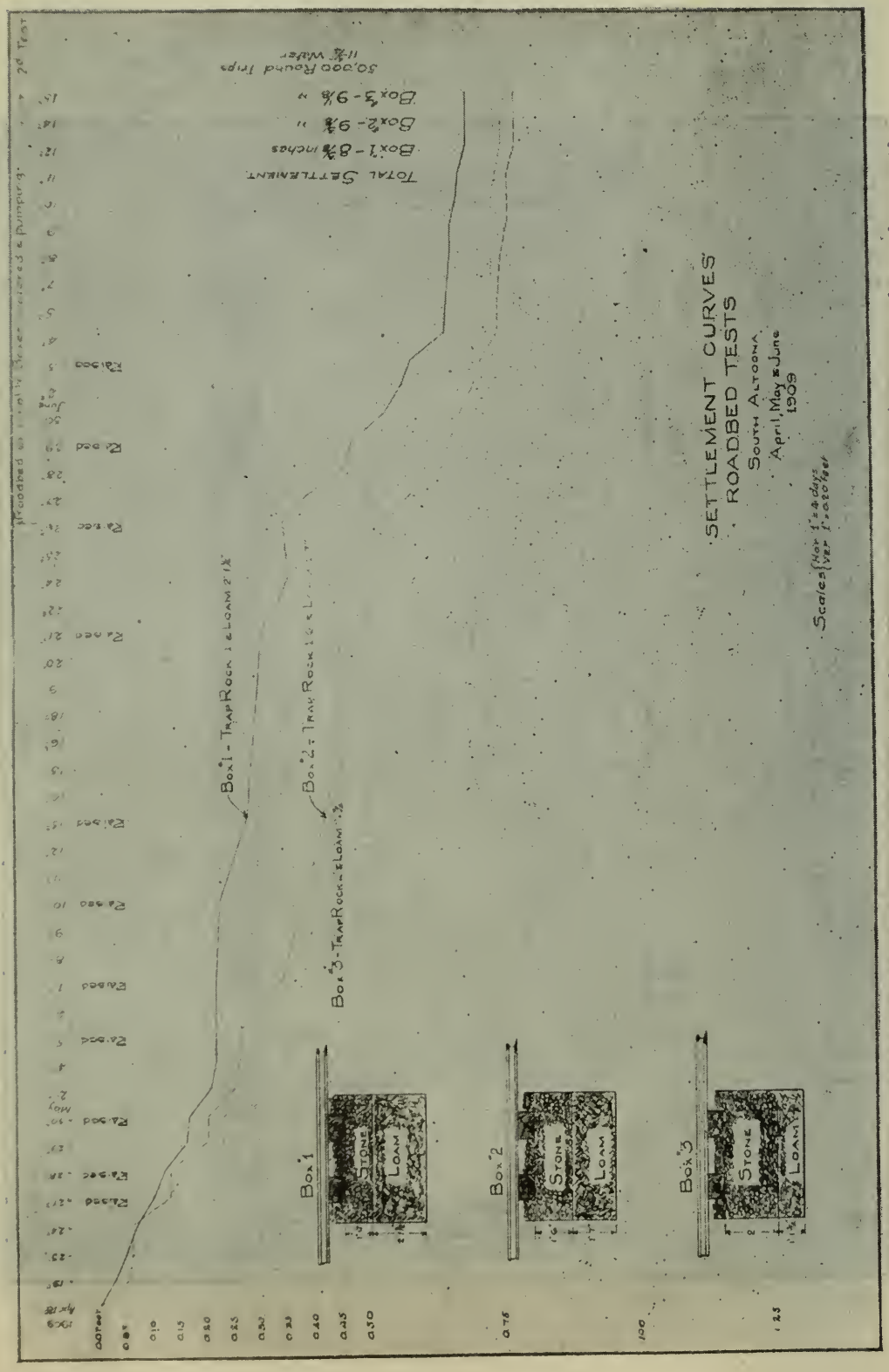

Test 2-Box 3-East Rail-Under Rail


Test 2 - Box 3 - West Rail - Under Rail.


2nd Test
Sections Looking Through Box
East Rail
P.R.R. Standard 85# Rail
South
Box N°3
16½"
P.R.R. Standard Square Tie
Original Dividing Line
Trap Rock Ballast
Loam
4' 10½"
Inside Length of Wood Test Box 9'0"
2'
1'1¾"
4½"
3'4"


2nd Test
Sections Looking Through Box
West Rail
P.R.R. Standard 85# Rail
South
Box No 3
16½"
7"x9"x8½" (Old) Tie
P.R.R. (Old) Standard Square Tie
Original Dividing Line
Trap Rock Ballast
Loam
2'
1'1¾"
Scale 1"-1'
1909
Legend
Settlement Directly Under Rail
10" from End of Tie
" "
Under End of Tie


2nd Test
Box No 3.
Section Through Box at
Right Angles to Rail
East Rail
West Rail
White Oak Squared Tie 7.9.84
Trap Rock Ballast
Original Undrng Line Ballast & Subgrade
Loam
2'0"
0'4"
9'0"
2'0"
Legend
Settlement Under North Tie
" South Tie
" Between Ties
1909
Scale 1"=1'


SETTLEMENT CURVES
ROADBED TESTS
SOUTH ALTOONA
April, May & June
1909
Box 1 - Trap Rock & Loam 2½"
Box 2 - Trap Rock & Loam 1½"
Box 3 - Trap Rock & Loam 1½"
Box 1
Box 2
Box 3
Stone
Loam
Total Settlement
Box 1 - 8¾ inches
Box 2 - 9¾ "
Box 3 - 9¾ "
50,000 Round Trips
11% Water

TEST NO. 3.

June 28 to August 6, 1909.

MATERIAL IN BOXES.

Each box had directly under ties 24 in. of engine cinder free from clinkers, below which was 12 in. of rich loam. The loam was put into the boxes in layers of 6 in. in depth, firmly compacted, but not stamped hard. The cinder was filled in and forced under ties by using a short piece of plank as a stamper. The car was started June 28 and continued running until July 20, when 45,500 trips had been completed. Water was put on from the first in such quantity to correspond to one-half inch rainfall per day. By July 20 there had been added 8¾ in. of water.

The total settlement for 45,500 trips was as follows: Box No. 1, 8½ in.; box No. 2, 8⅛ in., and box No. 3, 7¾ in.

For the first few days it was found necessary to raise and tamp the track twice a day. The total settlement for the first five days was as follows: Box No. 1, 4 in.; box No. 2, 4⅜ in., and box No. 3, 3½ in. The thirteen days following, in which time more than five times as many trips were completed, show settlement for box No. 1 of 4½ in.; box No. 2, of 3¾ in., and box No. 3, of 4¼ in.

On July 20, after the completion of 45,500 trips, it was thought advisable to begin the second part of test No. 3, to cut off 8 in. of cinder from the top of box No. 1, and 12 in. from the top of box No. 2, and fill in with clean trap rock ballast. The chief factor in determining the time at which to introduce stone ballast was the form of the settlement curve just previous to July 20. This curve at first fell off rapidly, gradually becoming less and less steep until the time of change, when it began to show signs of running nearly horizontally.

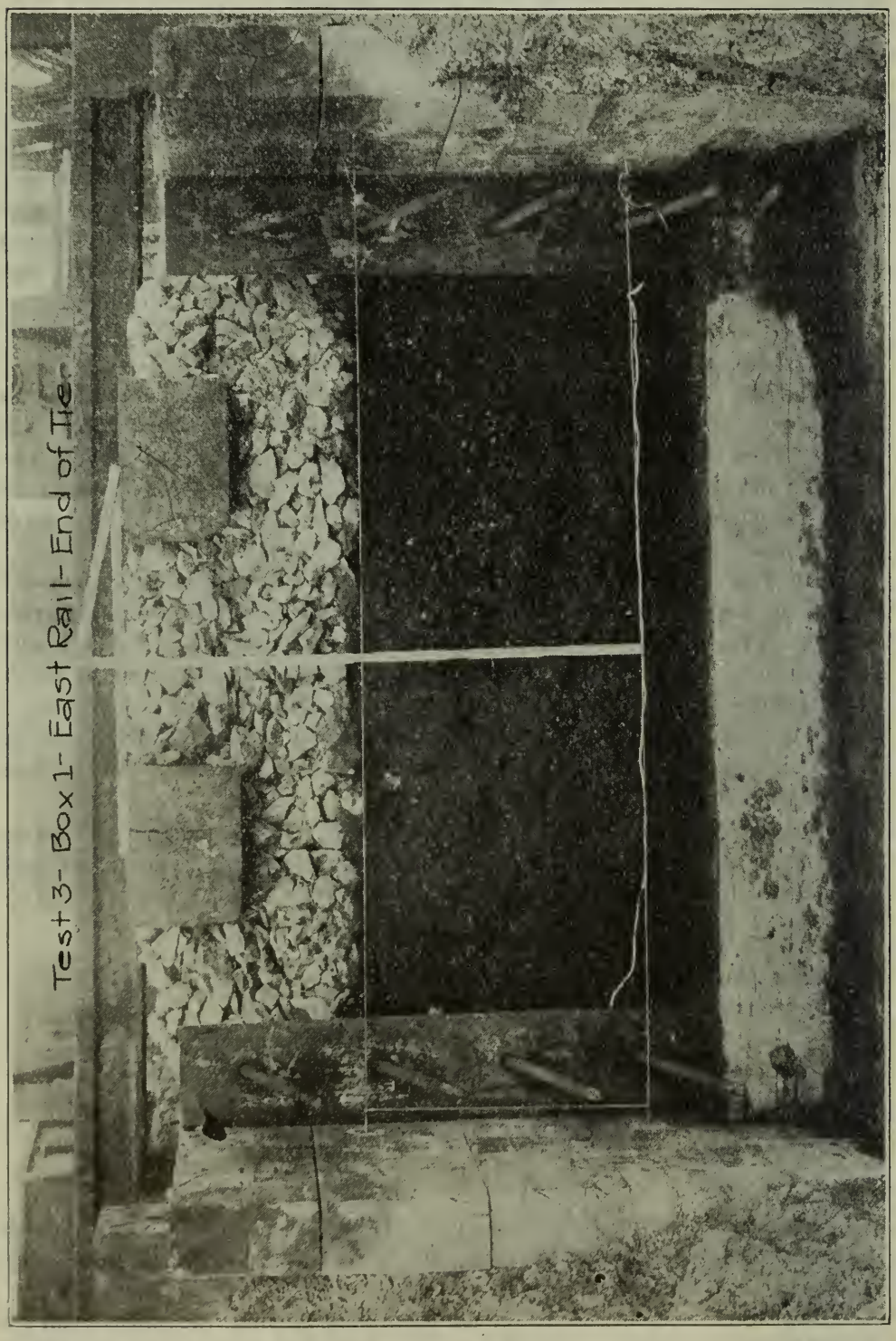
Box No. 3 was left as at first filled, and, with the changes in boxes Nos. 1 and 2 as indicated, the car began running on July 21 and continued until August 6, having made 40,100 additional trips.

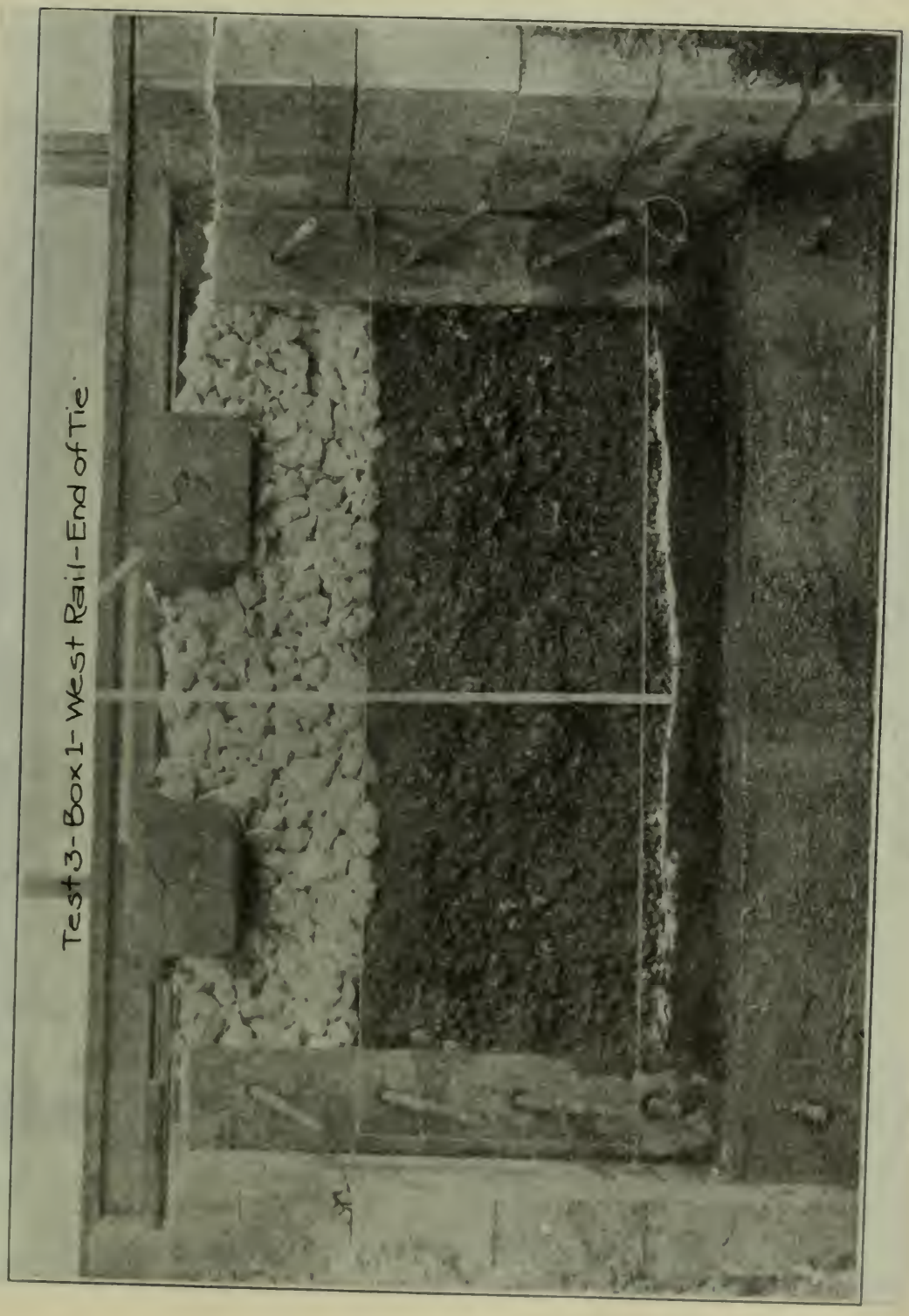
Statement of Conditions.

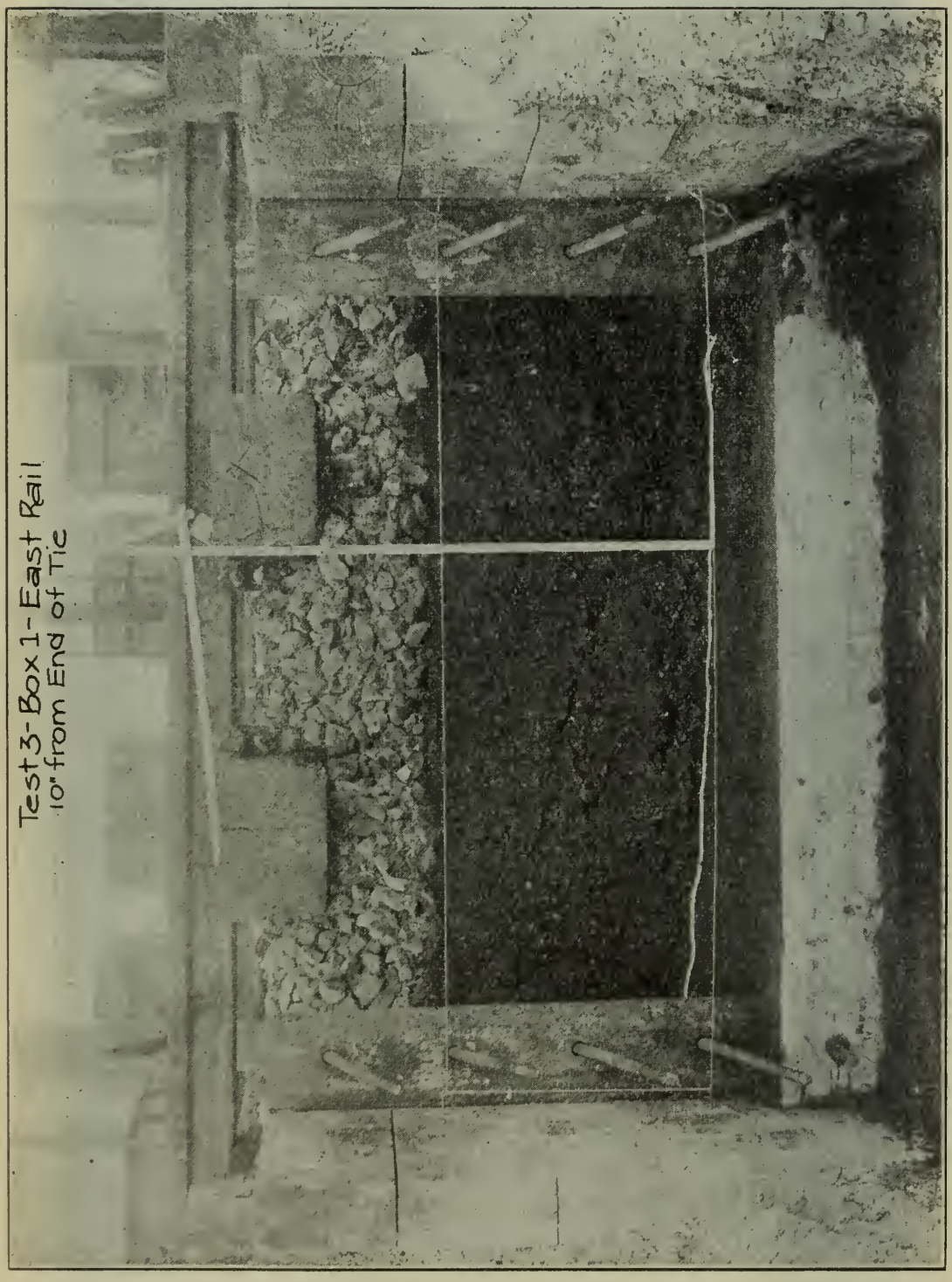
First part, 45,500 trips.		Second part, 40,100 trips.
Each box contained 12 in. of loam and 24 in. of cinder.	Box No. 1	8 in. cinder removed and 8 in. trap rock ballast added.
	Box No. 2	12 in. cinder removed and 12 in. trap rock ballast added.
	Box No. 3	Remained as in first part of test.

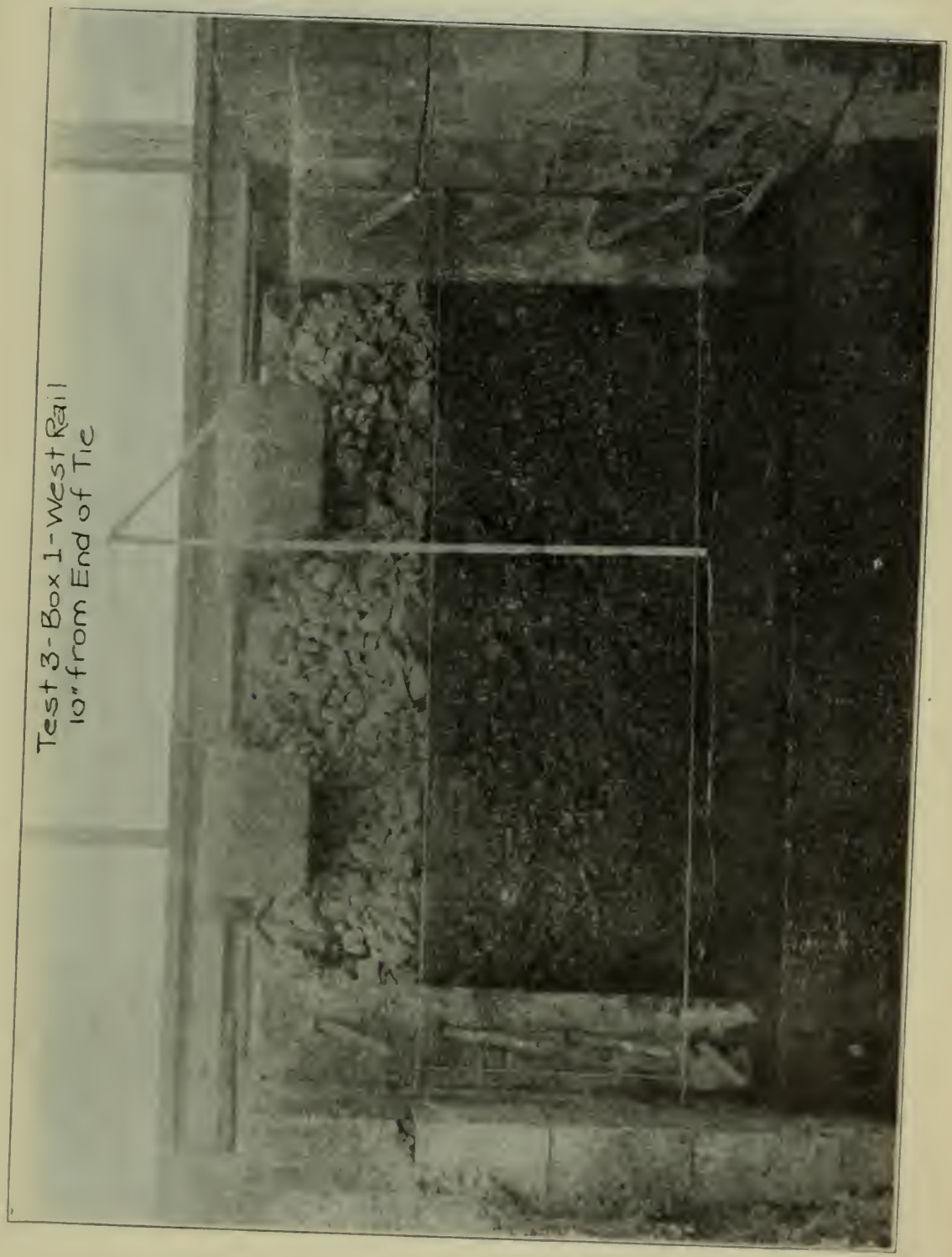
The settlement for the second part of the test from July 21 to August 6, was as follows: Box No. 1, 2¾ in.; box No. 2, 2⅞ in., and box No. 3, 2⅜ in.

The total amount of water on each box during the entire run of 85,600 trips was 15¾ in., extending over a period of 32 days, or an average of about one-half inch per day.

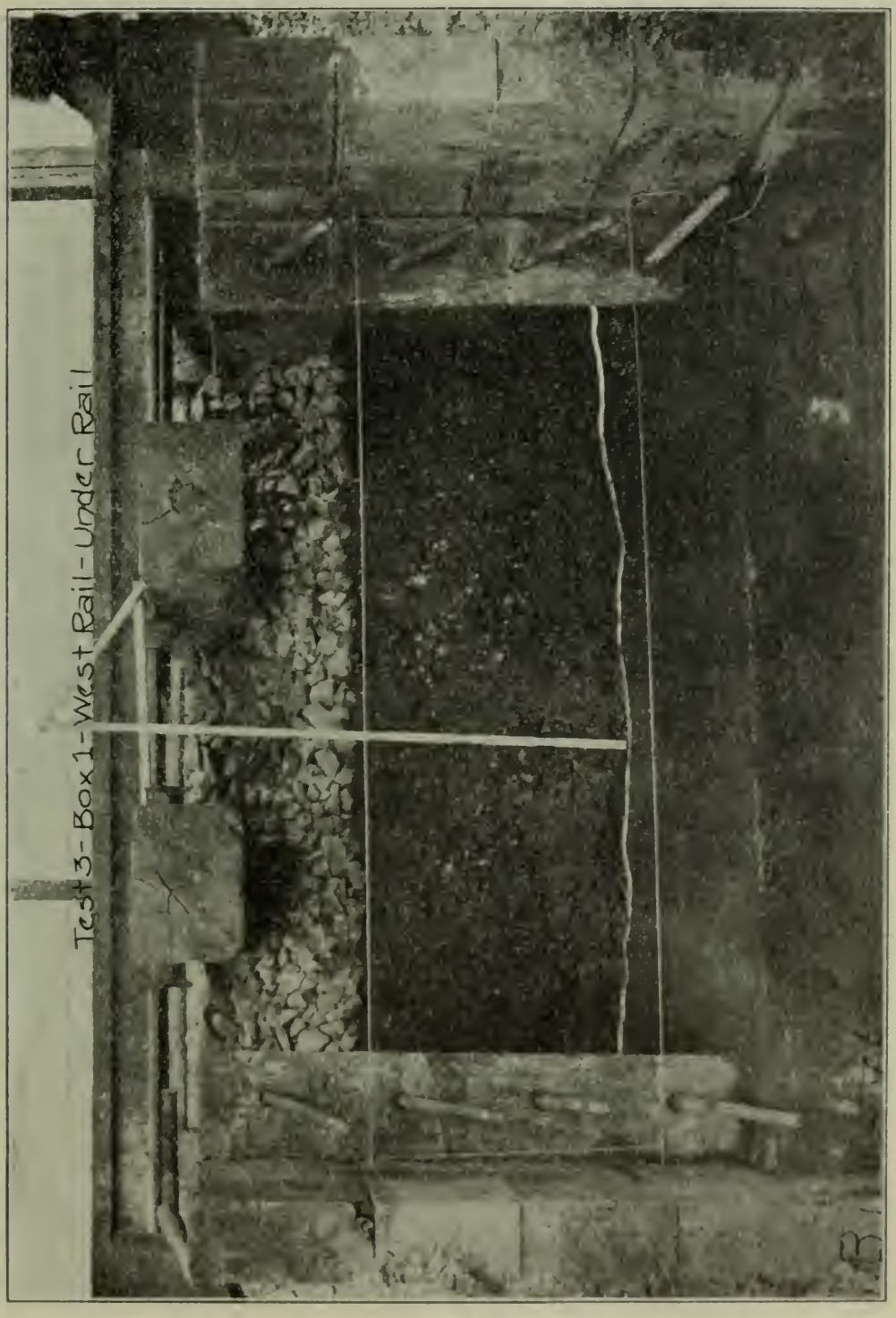

Test 3- Box 1- East Rail- End of Tie

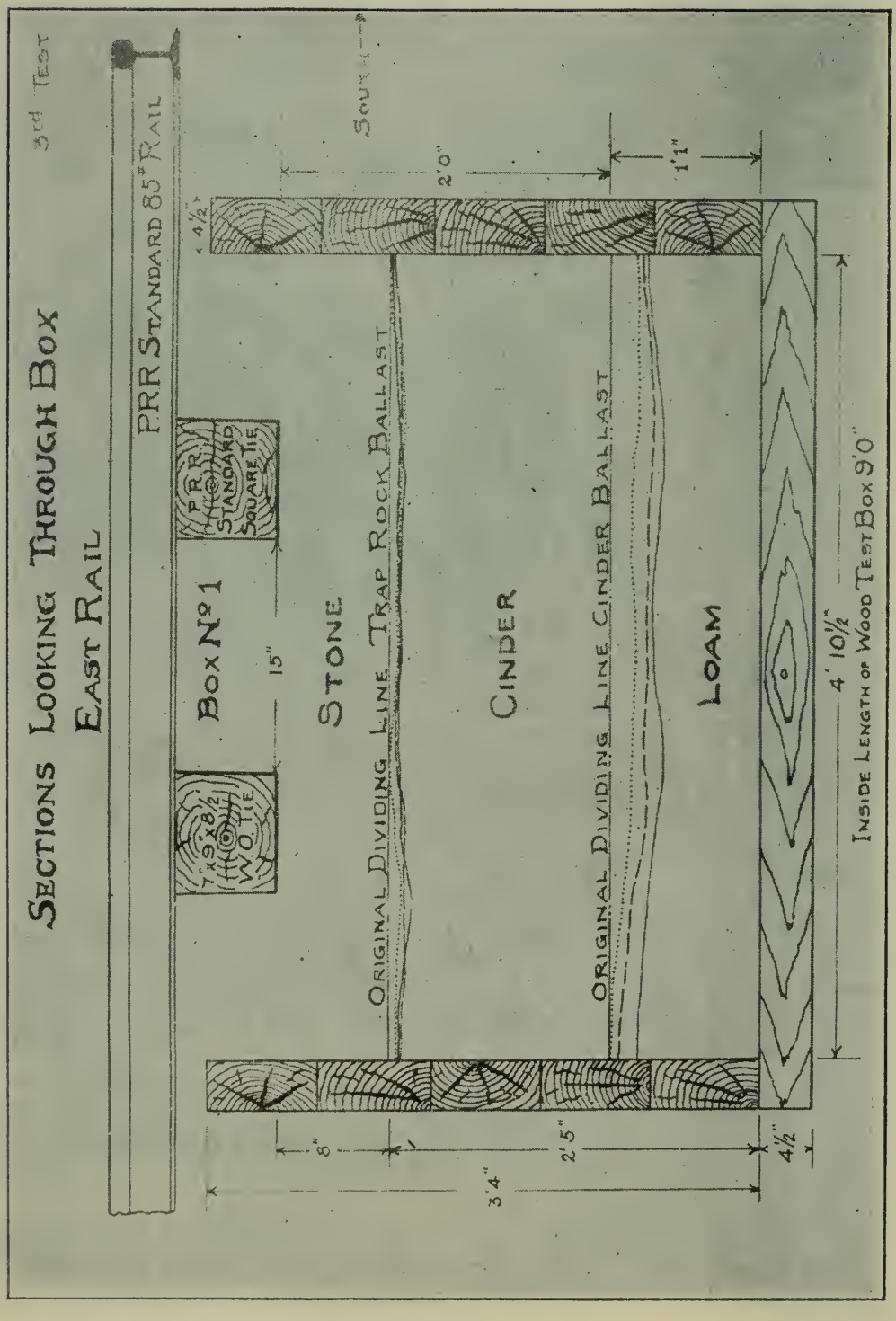

Test 3- Box 1- West Rail- End of Tie.

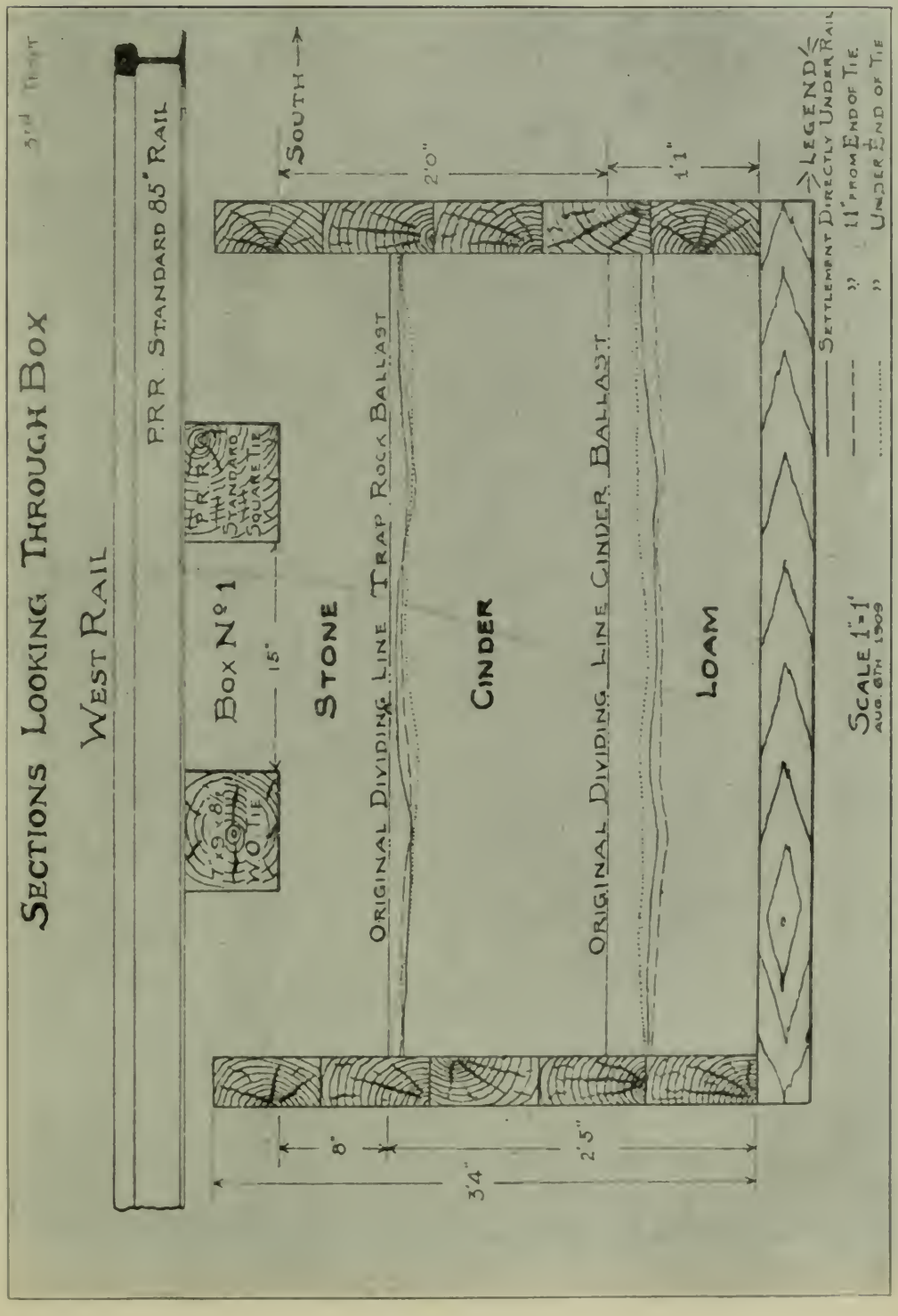

Test 3- Box 1- East Rail
10" from End of Tie

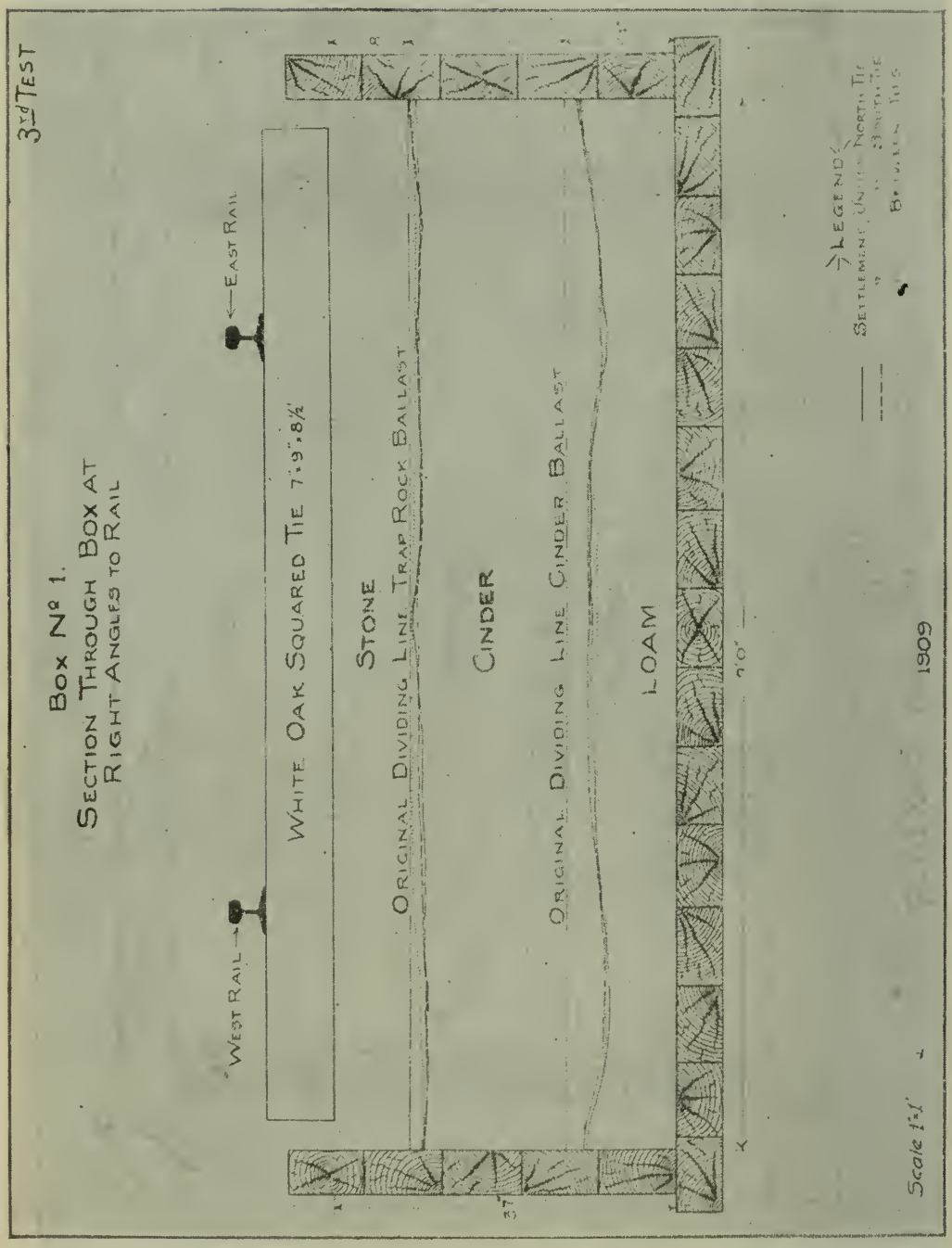

Test 3 - Box 1 - West Rail
10" from End of Tie

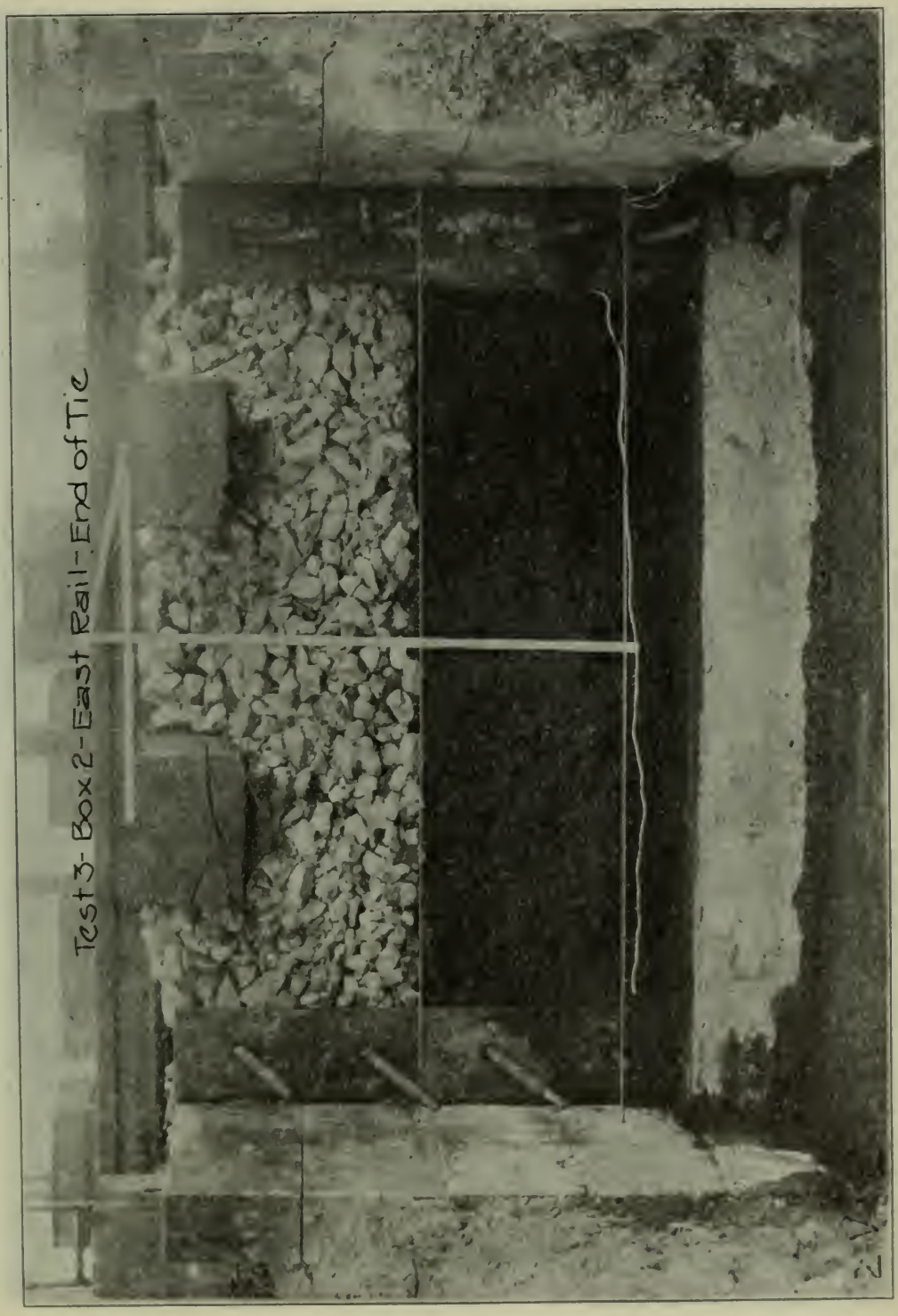
Test 3- Box 1- East Rail-Under Rail

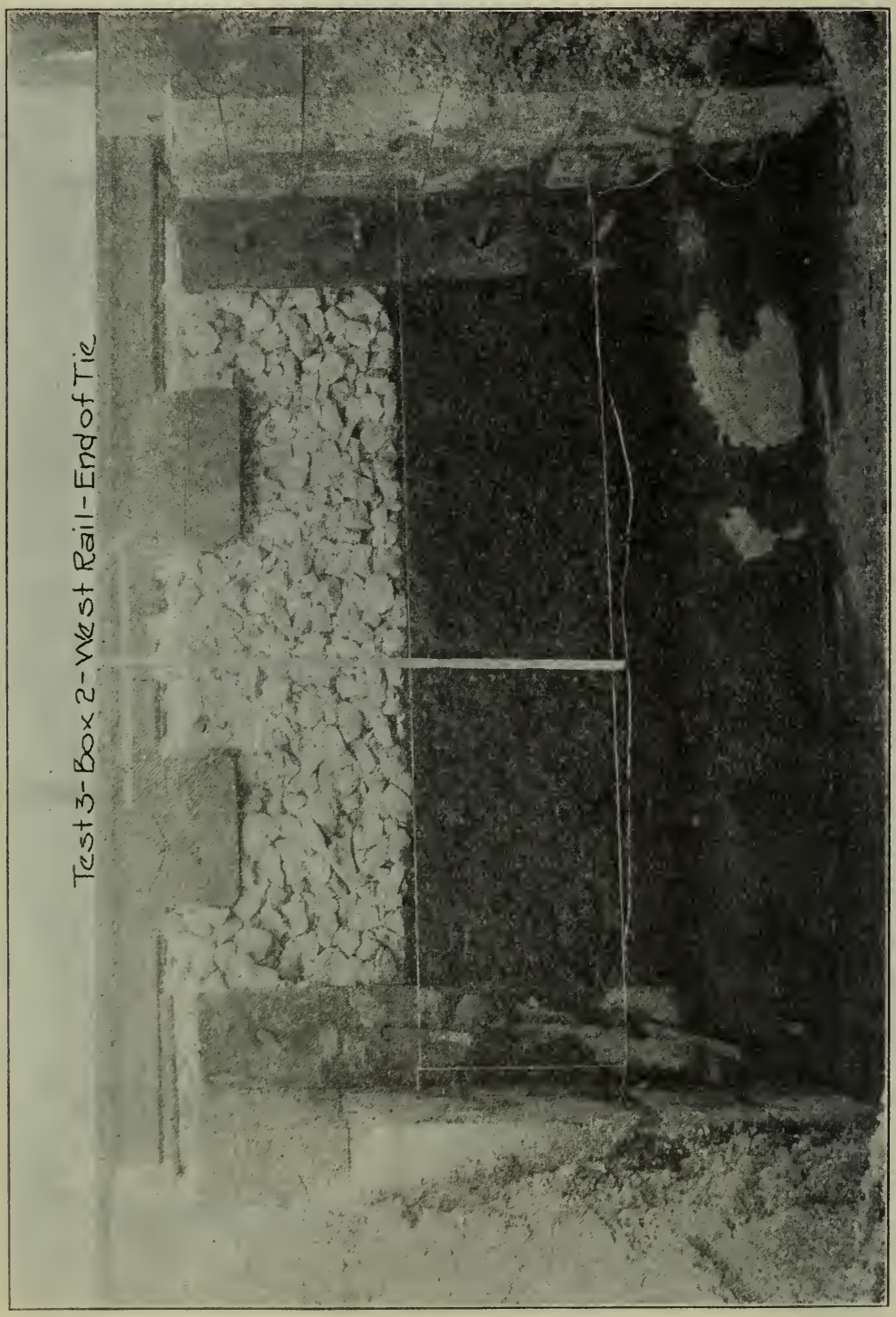

Test 3- Box 1- West Rail- Under Rail

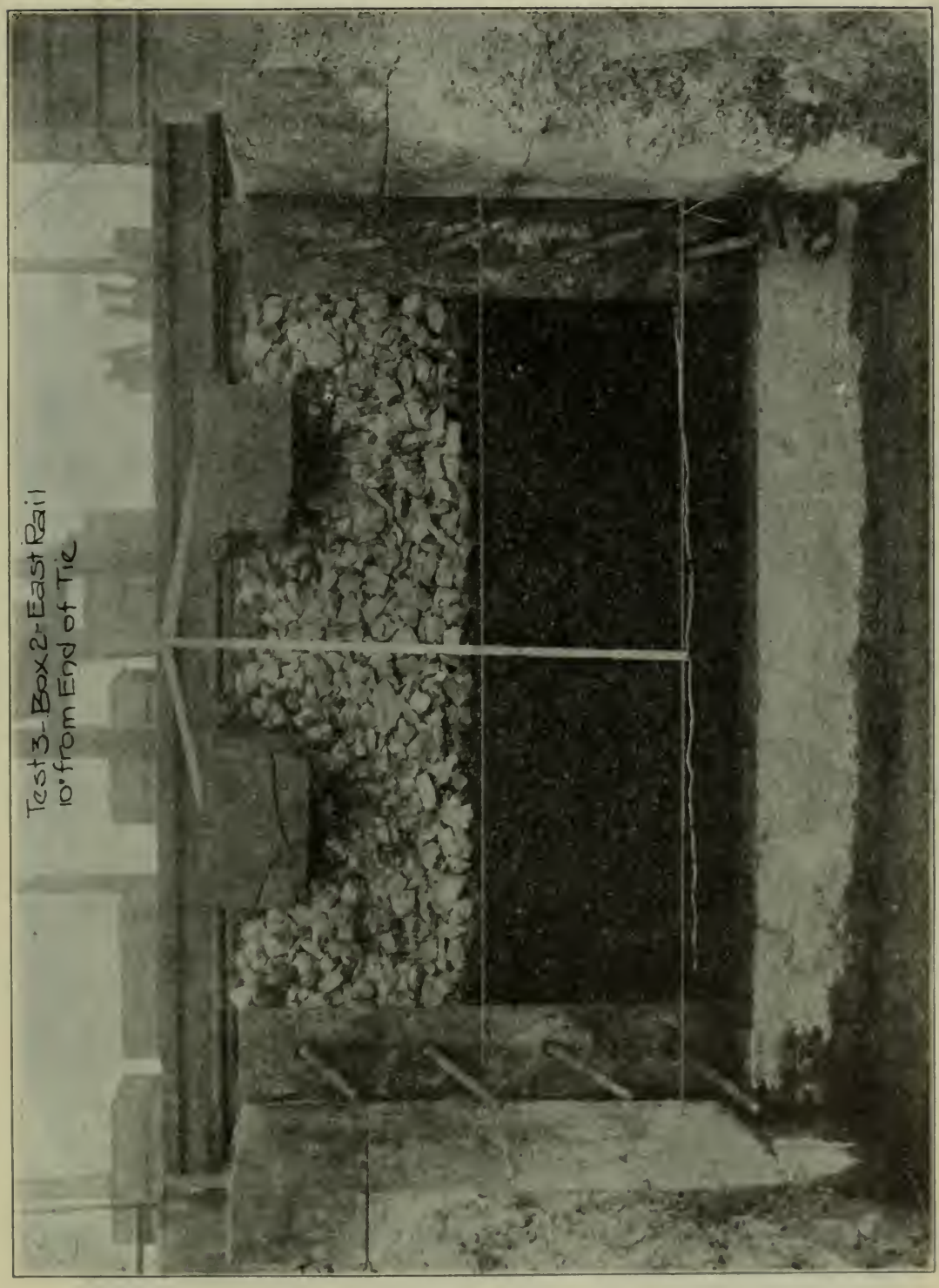

SECTIONS LOOKING THROUGH BOX
EAST RAIL
3rd TEST
PRR STANDARD 85# RAIL
BOX Nº 1
7"x9"x8½" W.O. TIE
P.R.R. STANDARD SQUARE TIE
15"
STONE
CINDER
LOAM
ORIGINAL DIVIDING LINE TRAP ROCK BALLAST
ORIGINAL DIVIDING LINE CINDER BALLAST
SOUTH
4½"
2'0"
1'1"
8"
2'5"
3'4"
4½"
4' 10½"
INSIDE LENGTH OF WOOD TEST BOX 9'0"

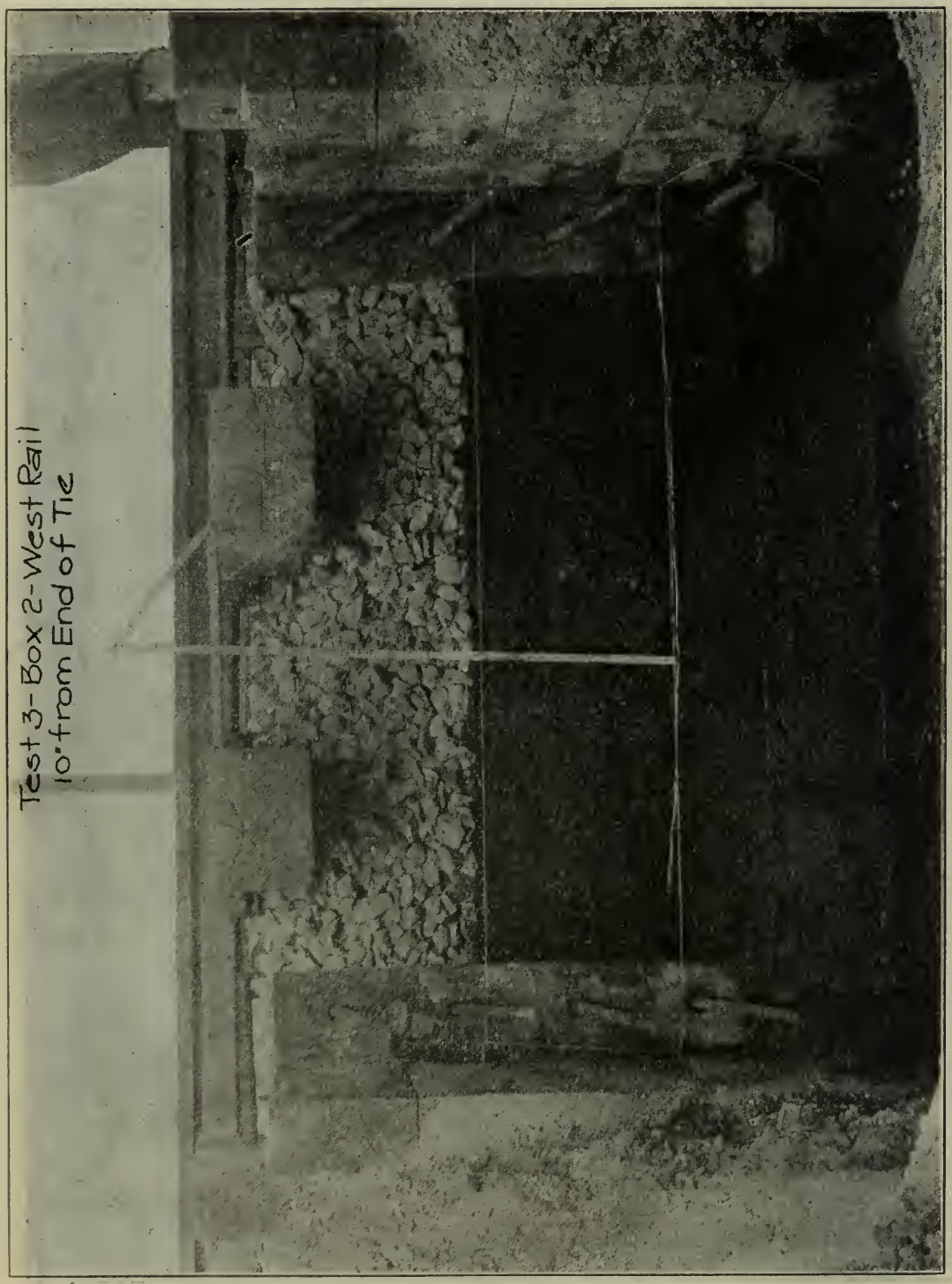

SECTIONS LOOKING THROUGH BOX
WEST RAIL
P.R.R. STANDARD 85# RAIL
BOX Nº 1
15"
STONE
CINDER
LOAM
ORIGINAL DIVIDING LINE TRAP ROCK BALLAST
ORIGINAL DIVIDING LINE CINDER BALLAST
SOUTH
2'0"
1'1"
8"
2'5"
3'4"
LEGEND
SETTLEMENT DIRECTLY UNDER RAIL
11" FROM END OF TIE
UNDER END OF TIE
SCALE 1"=1'
AUG. 6TH 1909

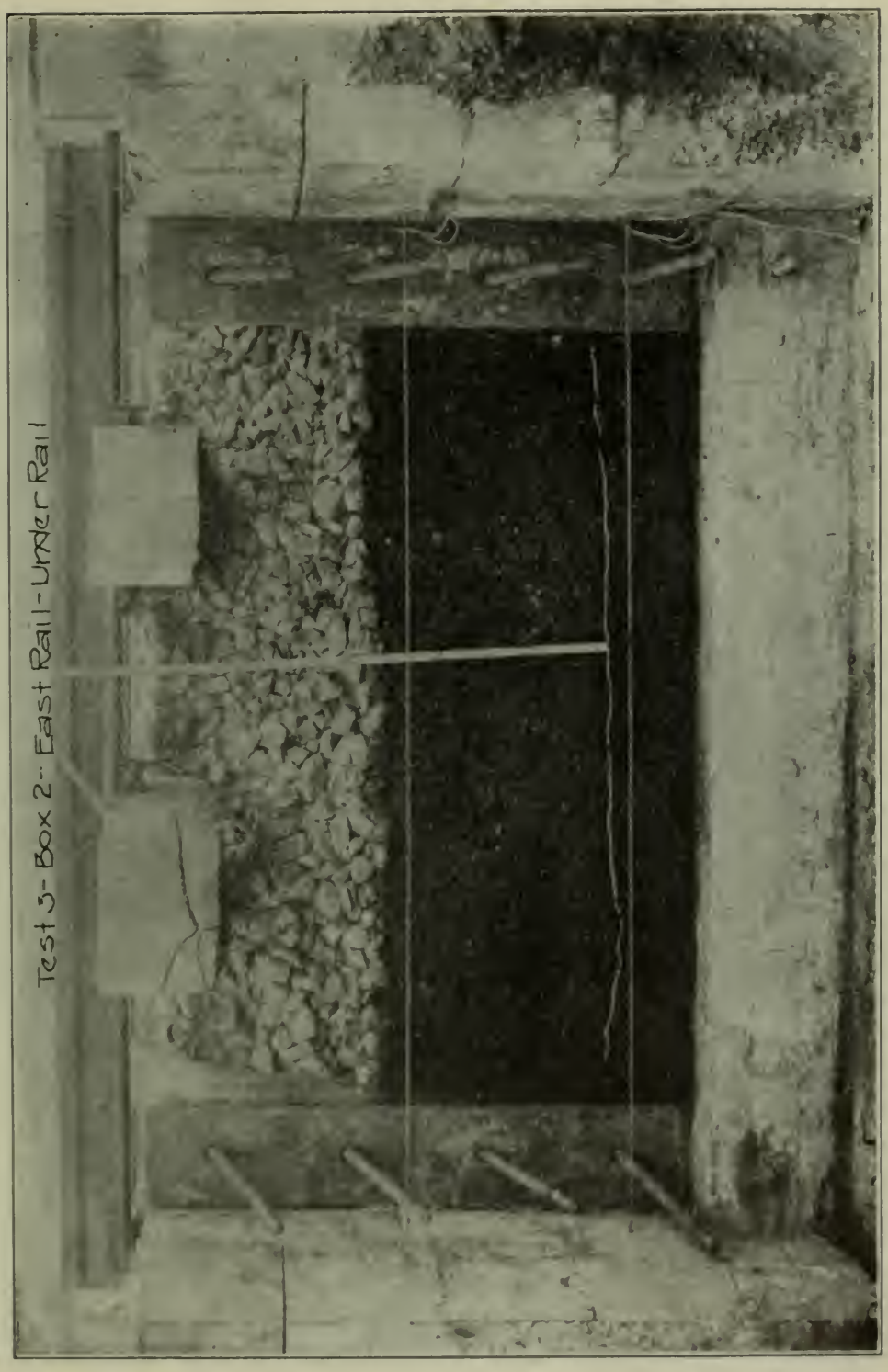

3rd Test
Box No 1.
Section Through Box at
Right Angles to Rail
West Rail
East Rail
White Oak Squared Tie 7'9",8¼'
Stone
Original Dividing Line, Trap Rock Ballast
Cinder
Original Dividing Line, Cinder Ballast
Loam
Legend
1909
Scale 1:1'

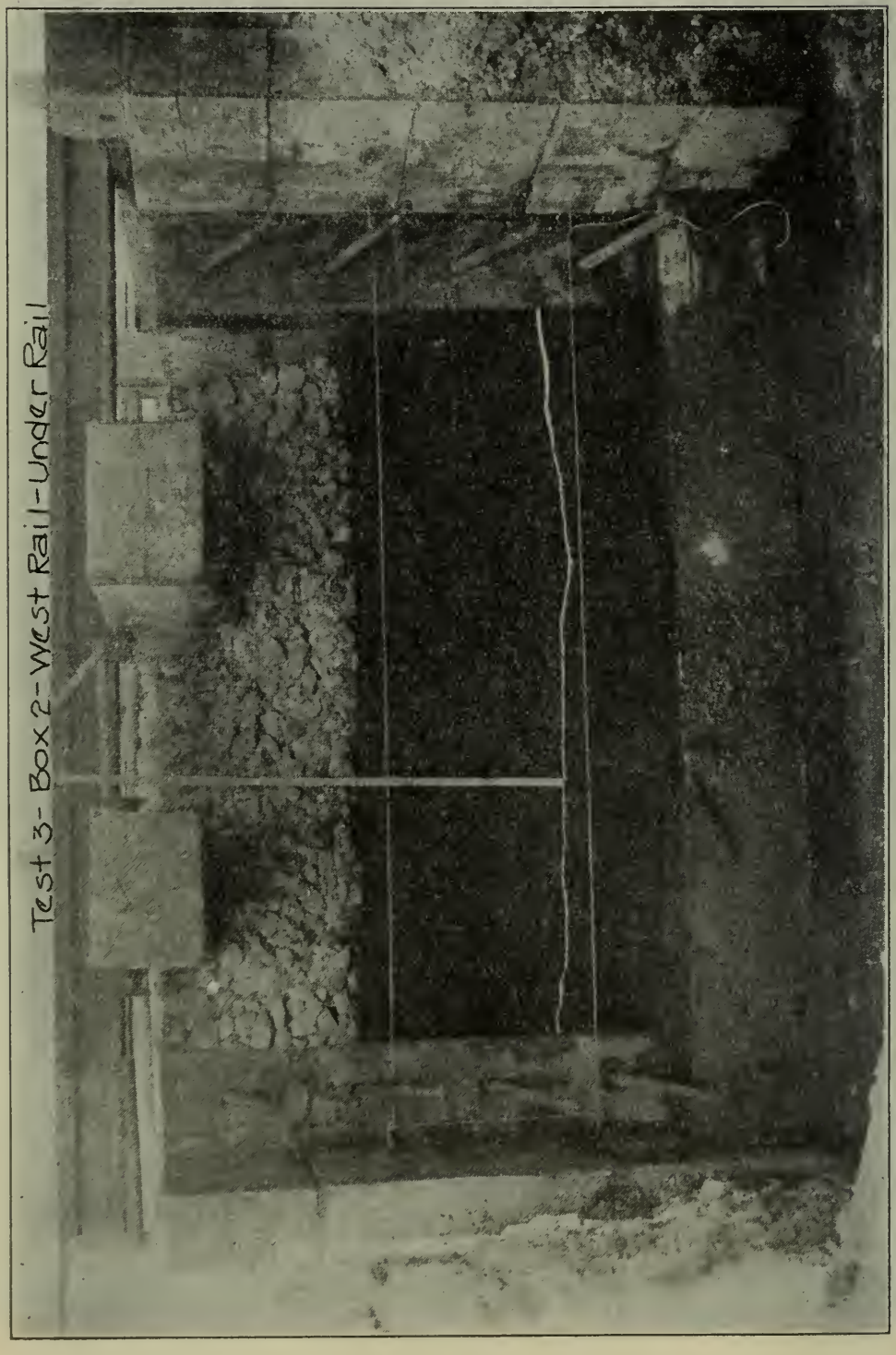

Test 3- Box 2- East Rail- End of Tie

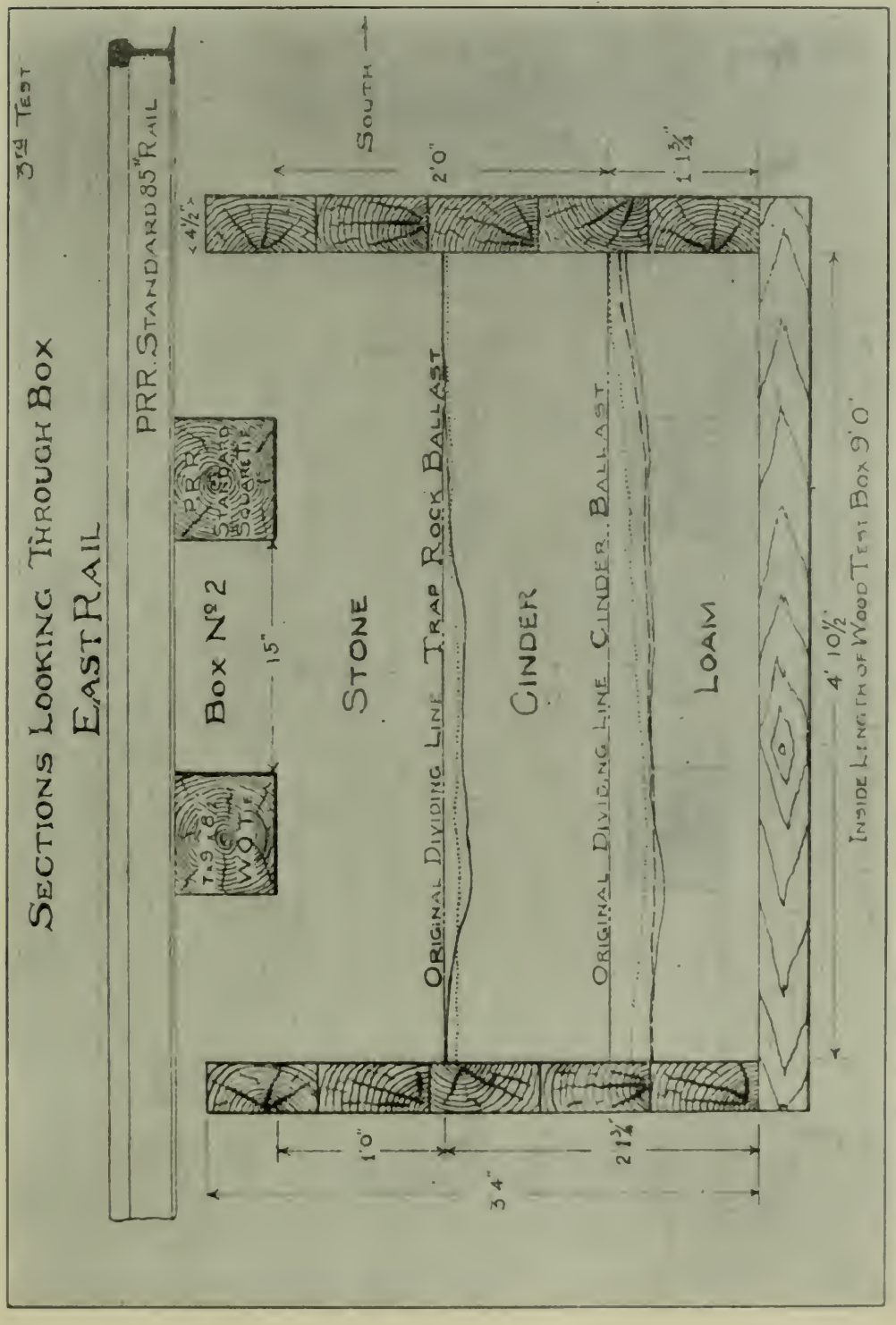

Test 3- Box 2- West Rail- End of Tie

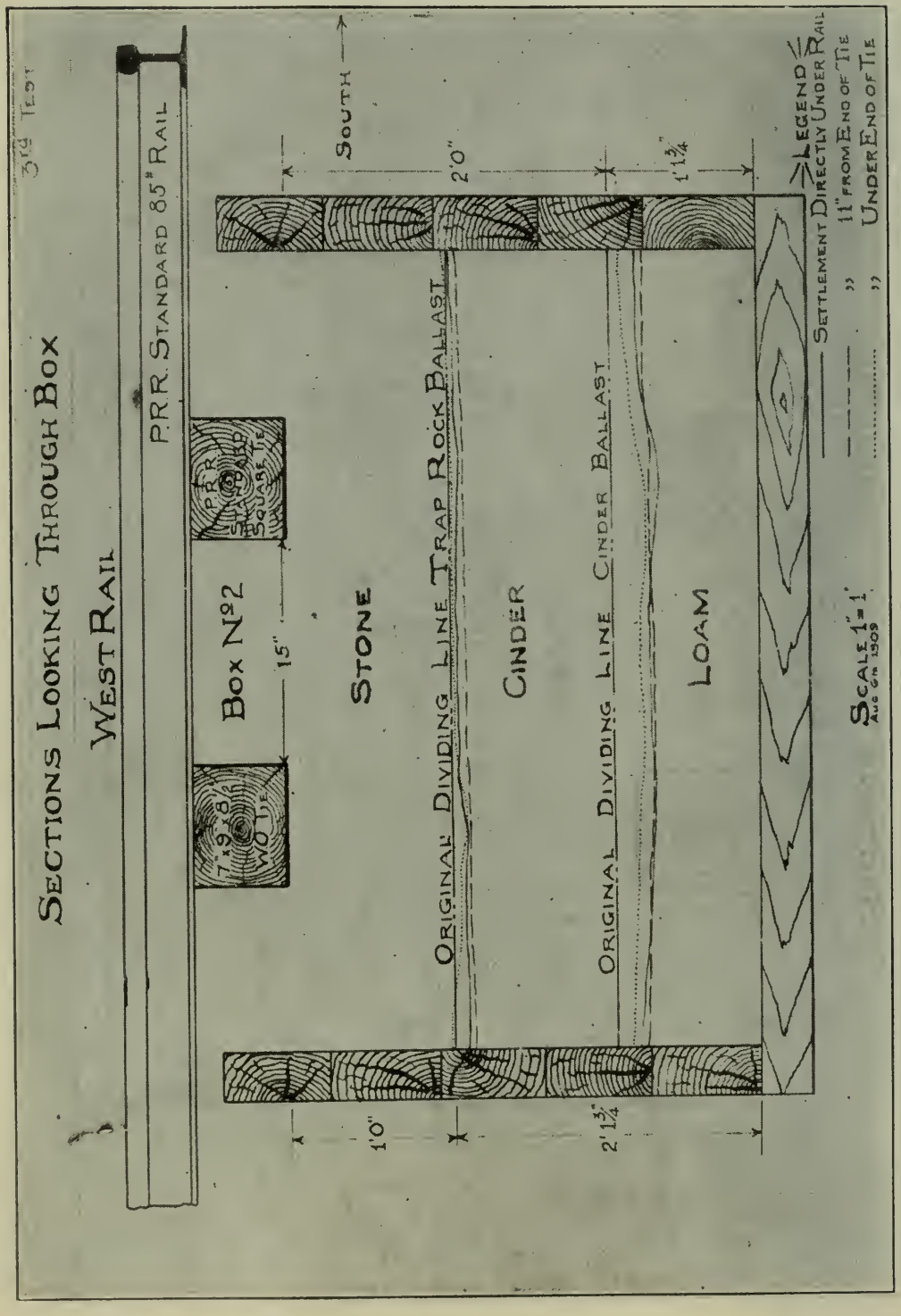

Test 3 - Box 2 - East Rail
10' from End of Tie

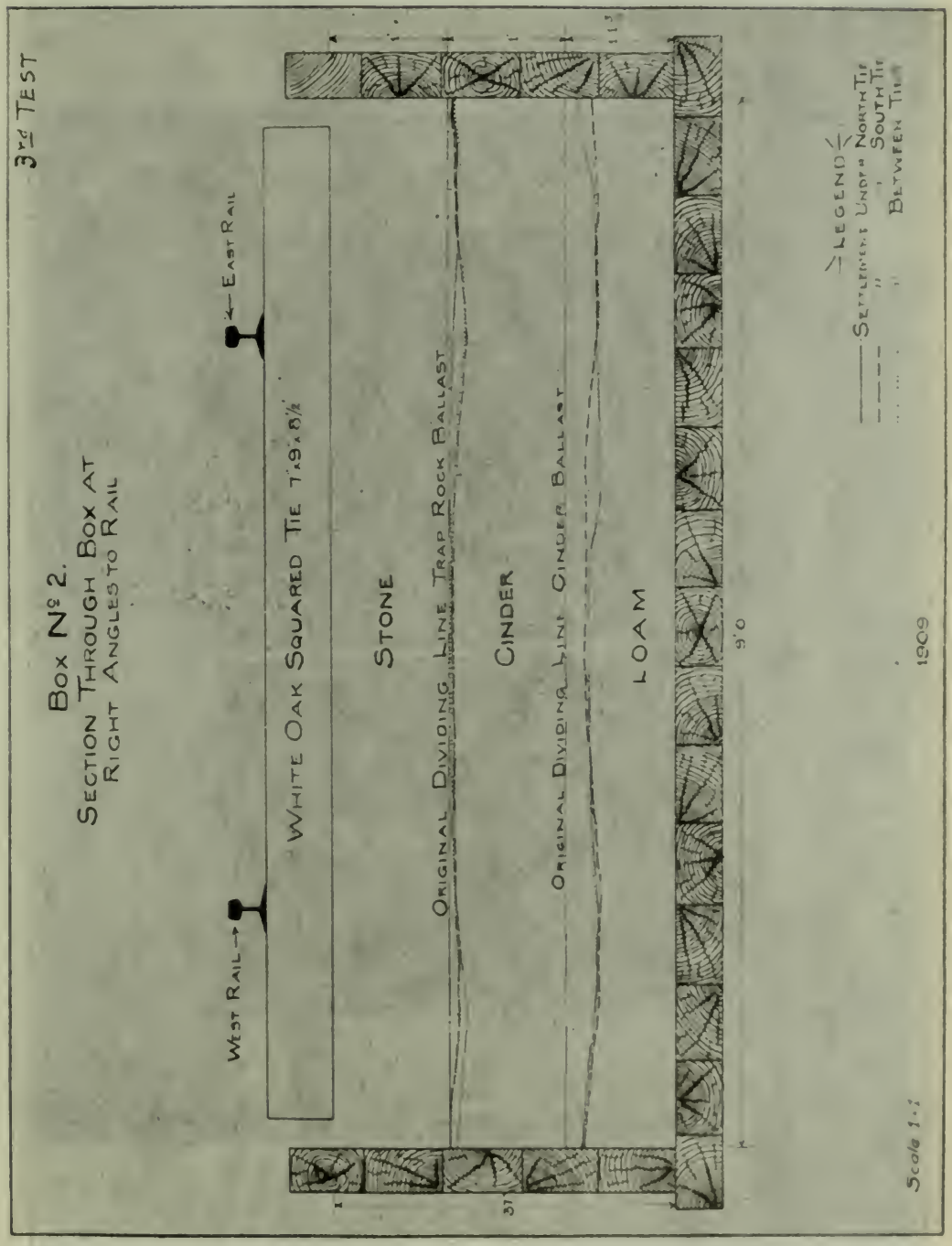

Test 3- Box 2-West Rail
10' from End of Tie

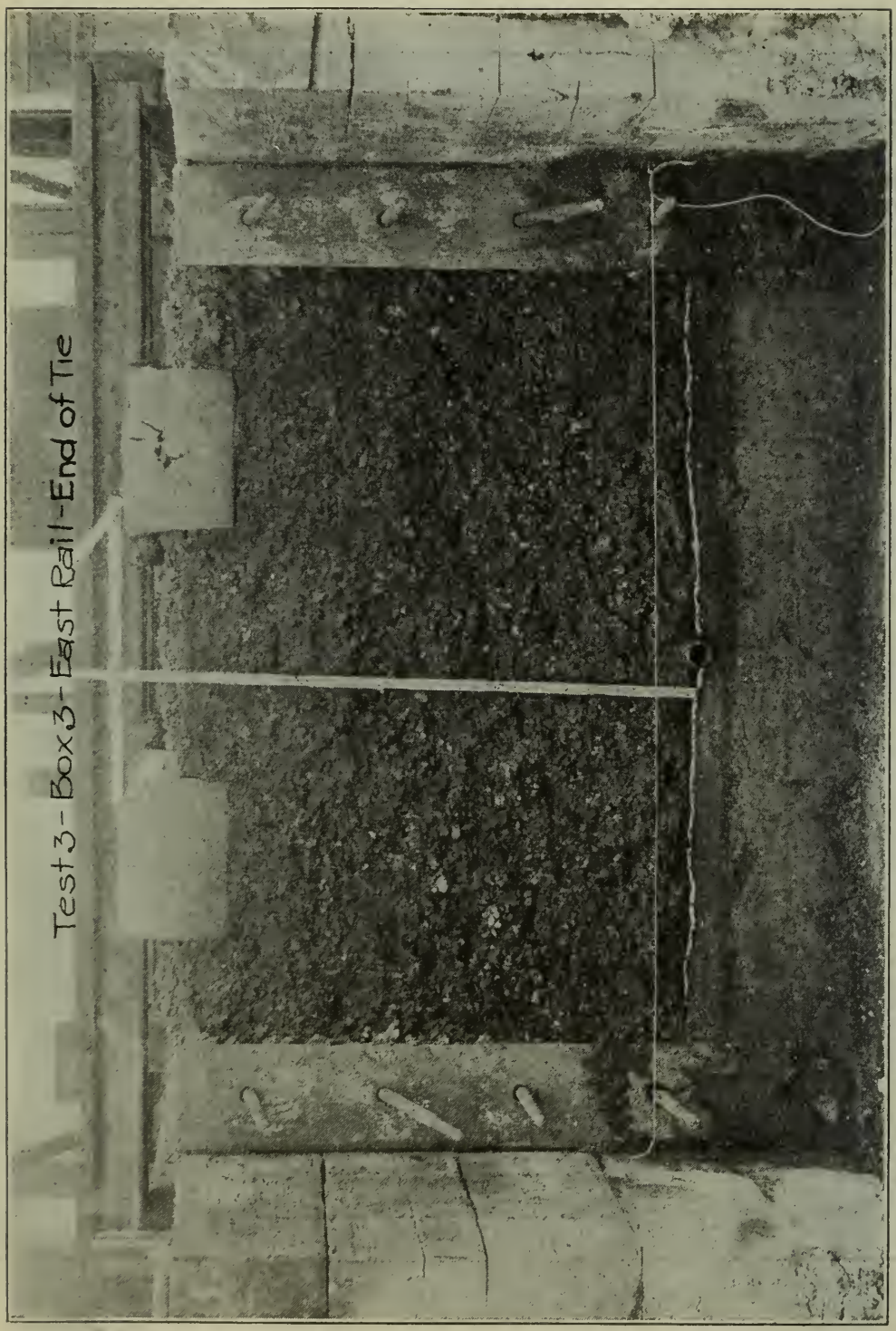

Test 5- Box 2- East Rail- Under Rail

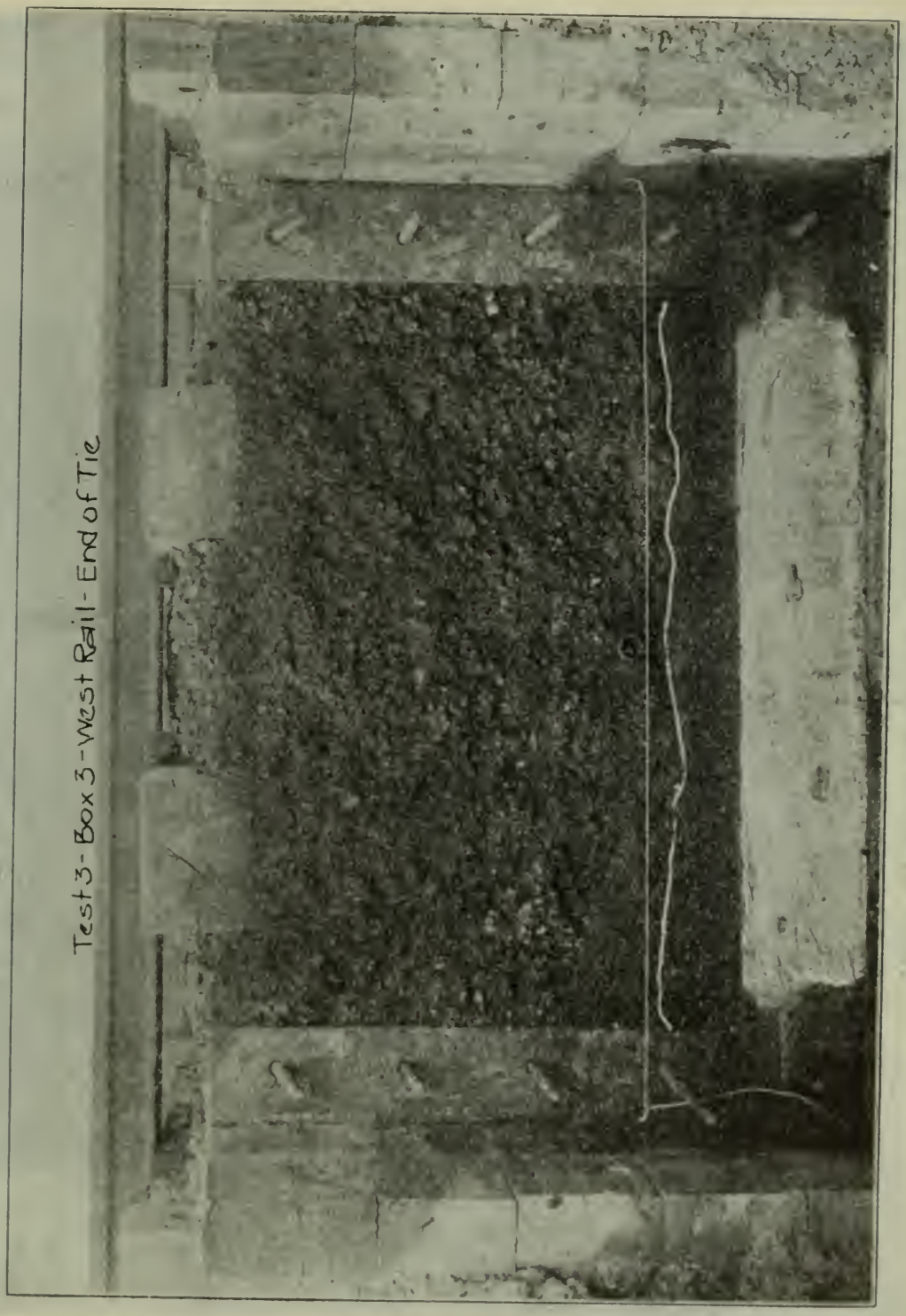

Test 3- Box 2- West Rail- Under Rail

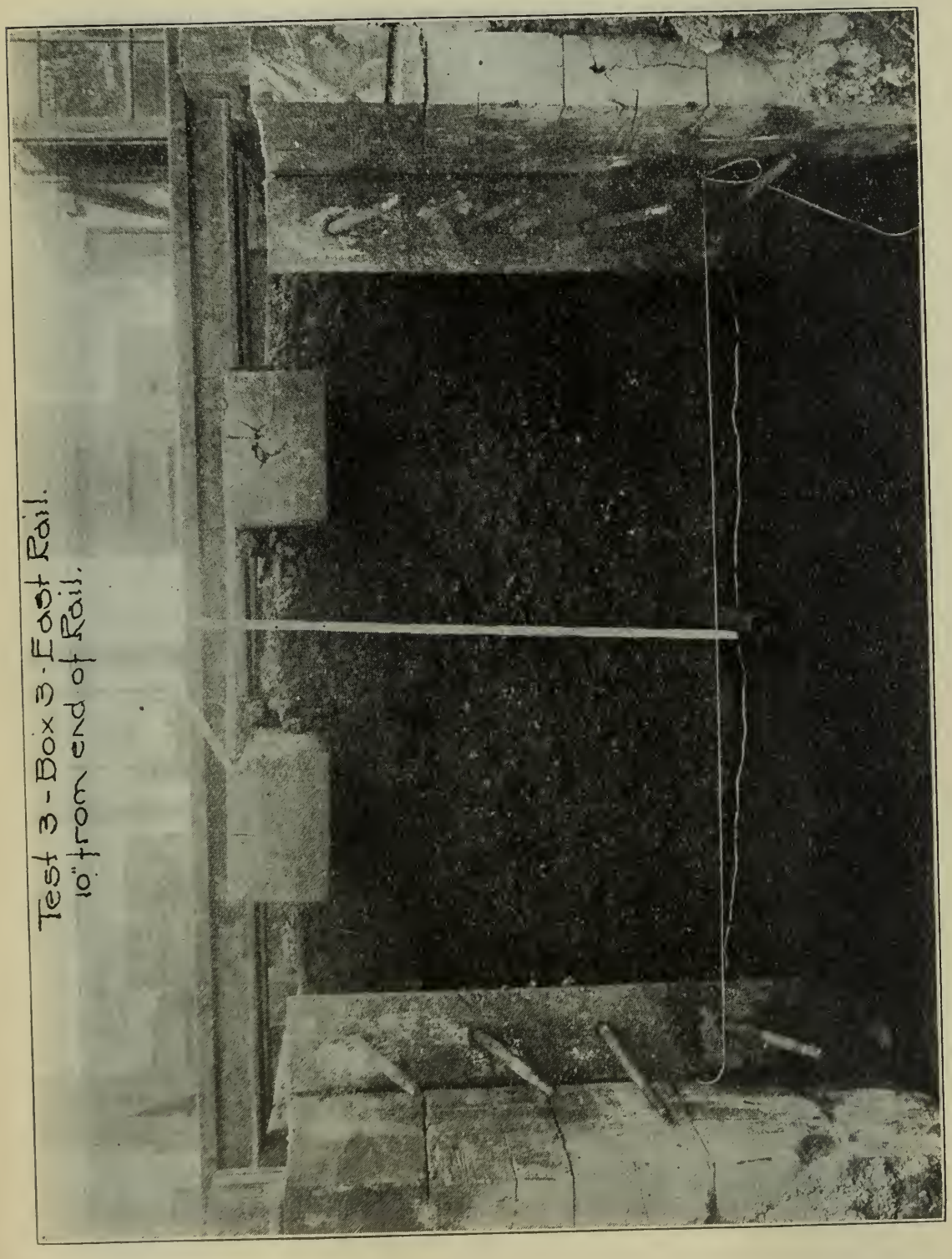

SECTIONS LOOKING THROUGH BOX
EAST RAIL
3rd TEST
PRR. STANDARD 85# RAIL
SOUTH
BOX Nº 2
15"
STONE
CINDER
LOAM
ORIGINAL DIVIDING LINE TRAP ROCK BALLAST
ORIGINAL DIVIDING LINE CINDER BALLAST
2'0"
1'0"
34"
21½"
4' 10½"
INSIDE LENGTH OF WOOD TEST BOX 9'0"

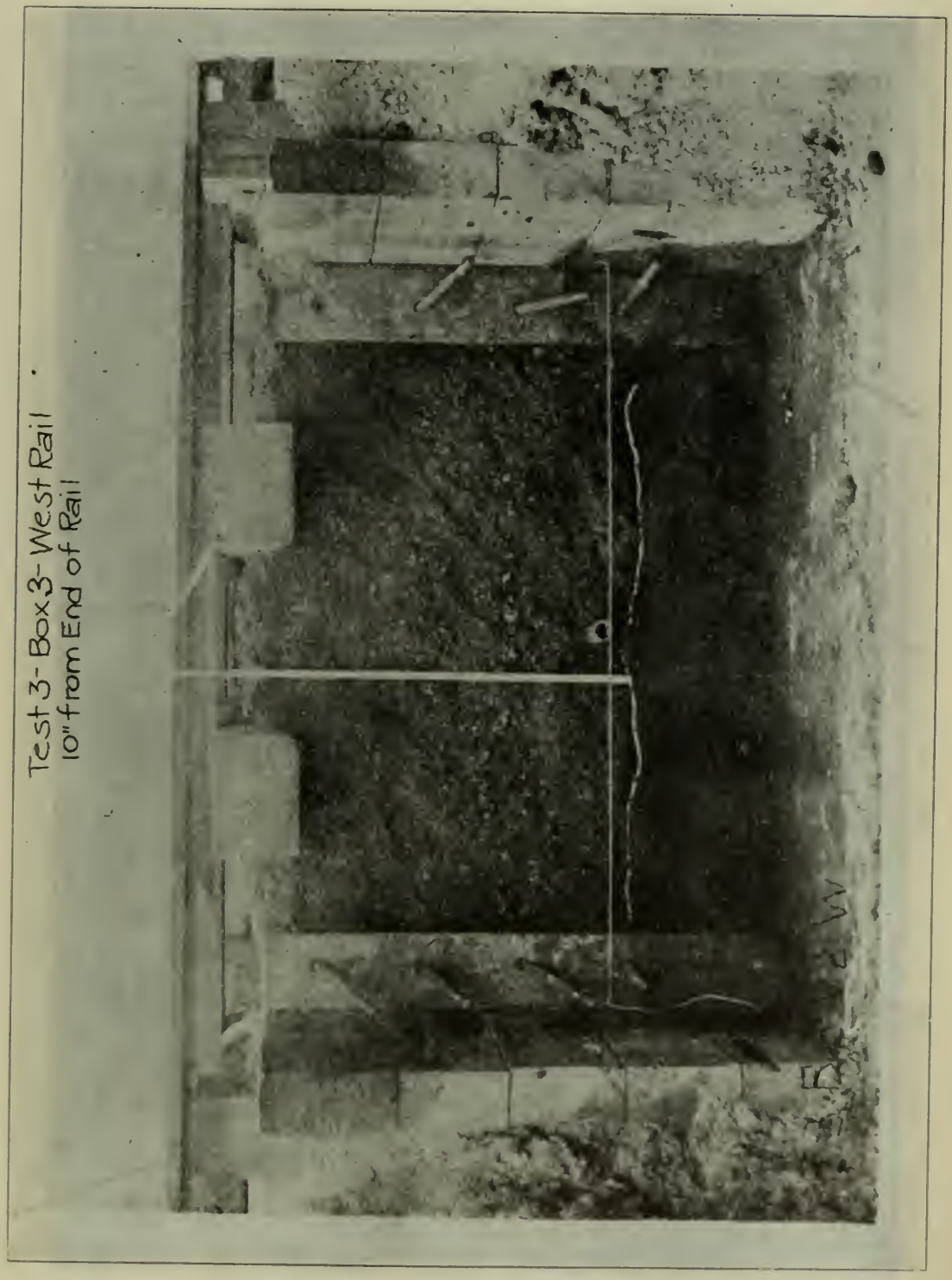

SECTIONS LOOKING THROUGH BOX
WEST RAIL
P.R.R. STANDARD 85# RAIL
BOX Nº2
15"
STONE
CINDER
LOAM
ORIGINAL DIVIDING LINE TRAP ROCK BALLAST
ORIGINAL DIVIDING LINE CINDER BALLAST
SOUTH
2'0"
1'1¾"
1'0"
2'1¾"
LEGEND
SETTLEMENT DIRECTLY UNDER RAIL
11" FROM END OF TIE
UNDER END OF TIE
SCALE 1"=1'

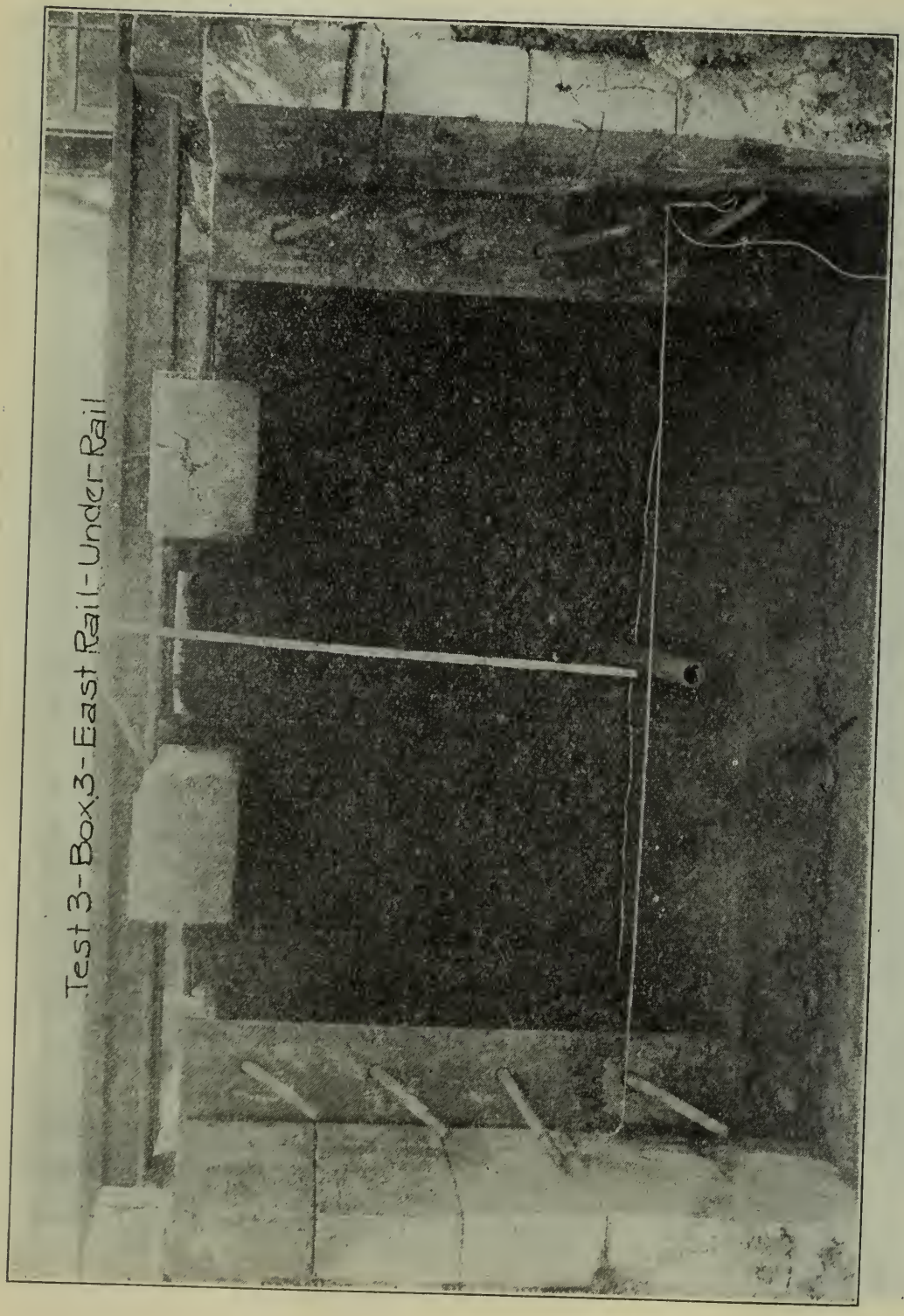

3rd Test
Box No 2.
Section Through Box at
Right Angles to Rail
East Rail
West Rail
White Oak Squared Tie 7'9"x8½"
Stone
Original Dividing Line Trap Rock Ballast
Cinder
Original Dividing Line Cinder Ballast
Loam
9'0
Legend
Settlement Under North Tie
" " South Tie
" " Between Tie
1909
Scale 1"

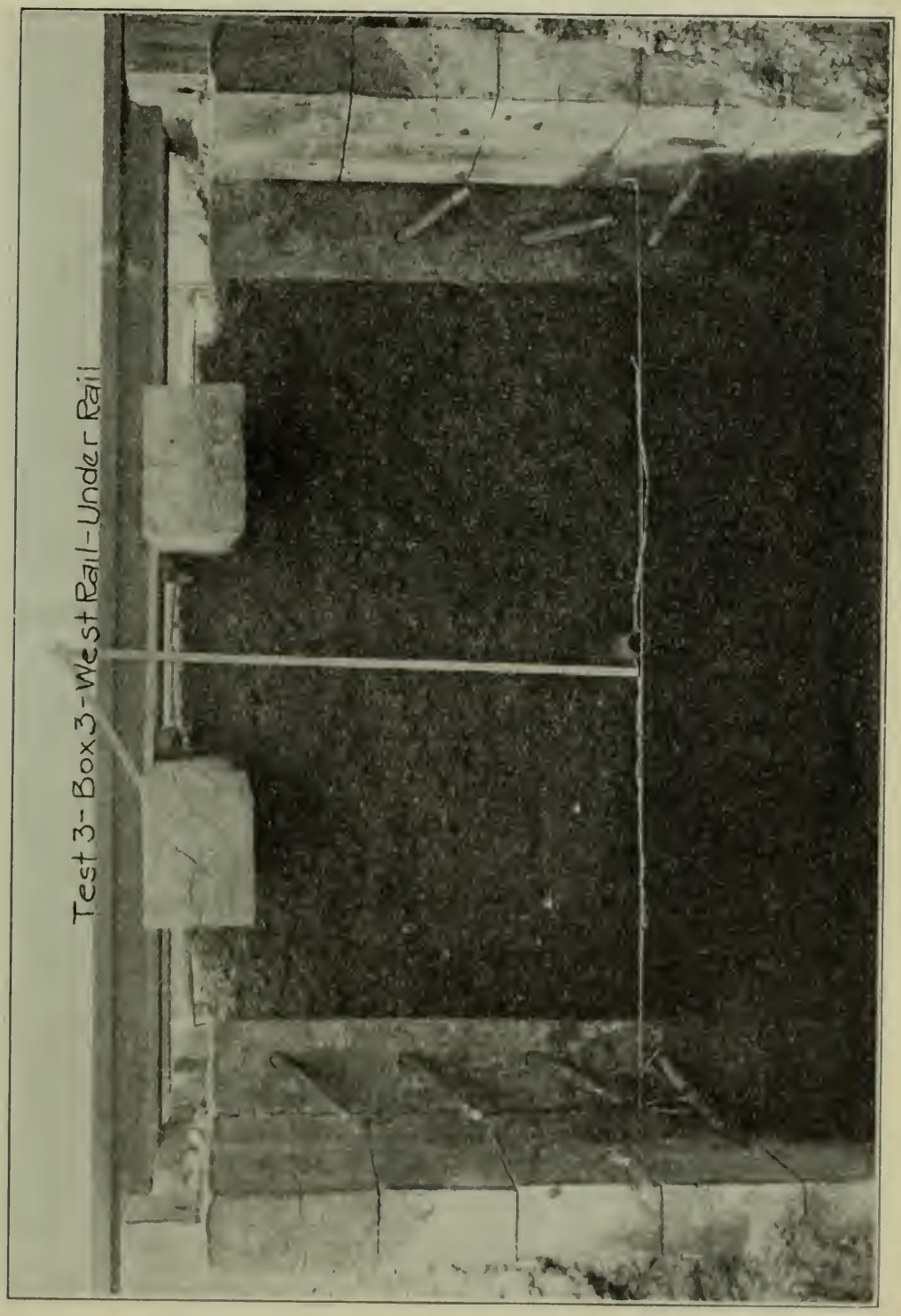

Test 3 - Box 3 - East Rail - End of Tie

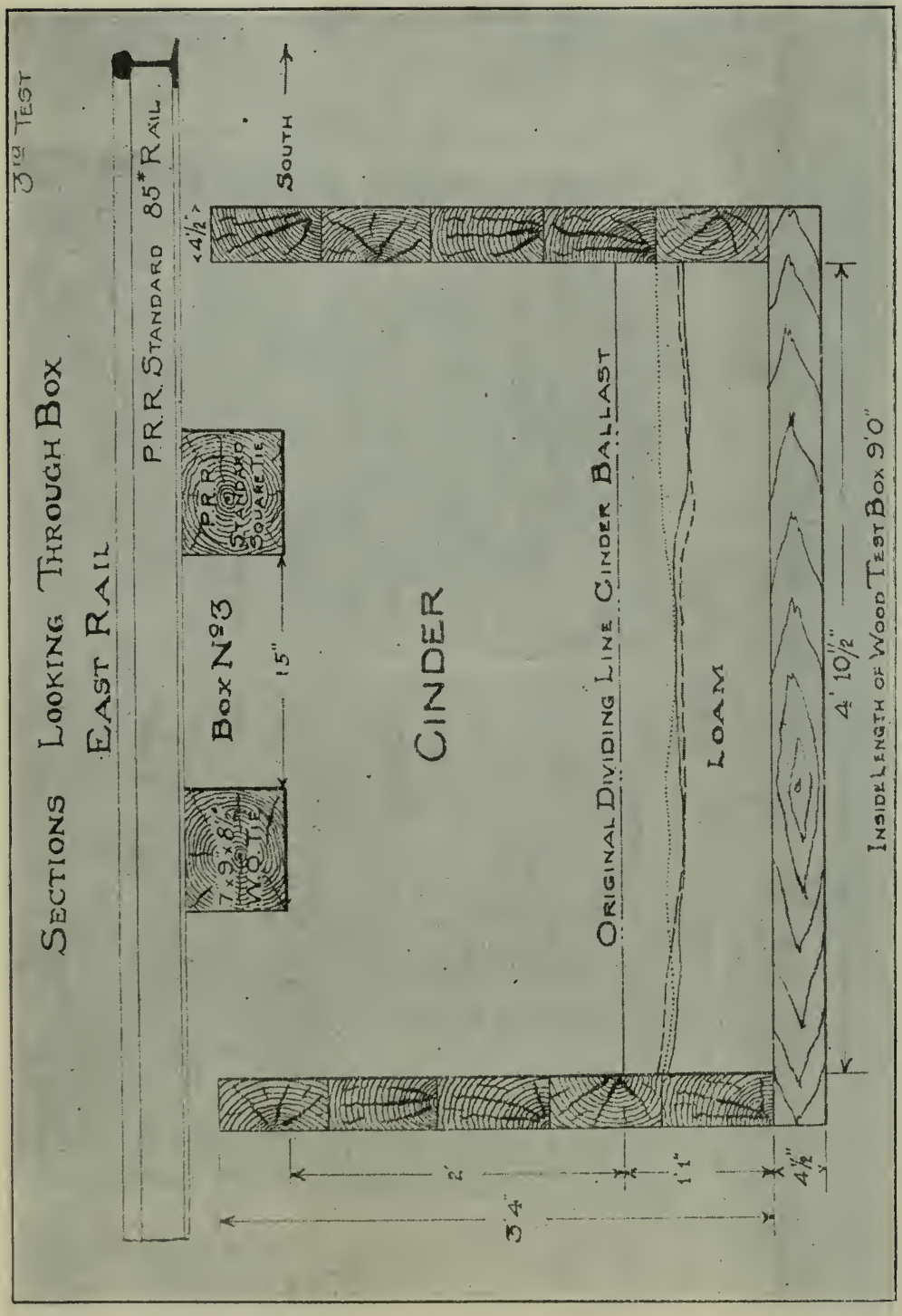

Test 3 - Box 3 - West Rail - End of Tie

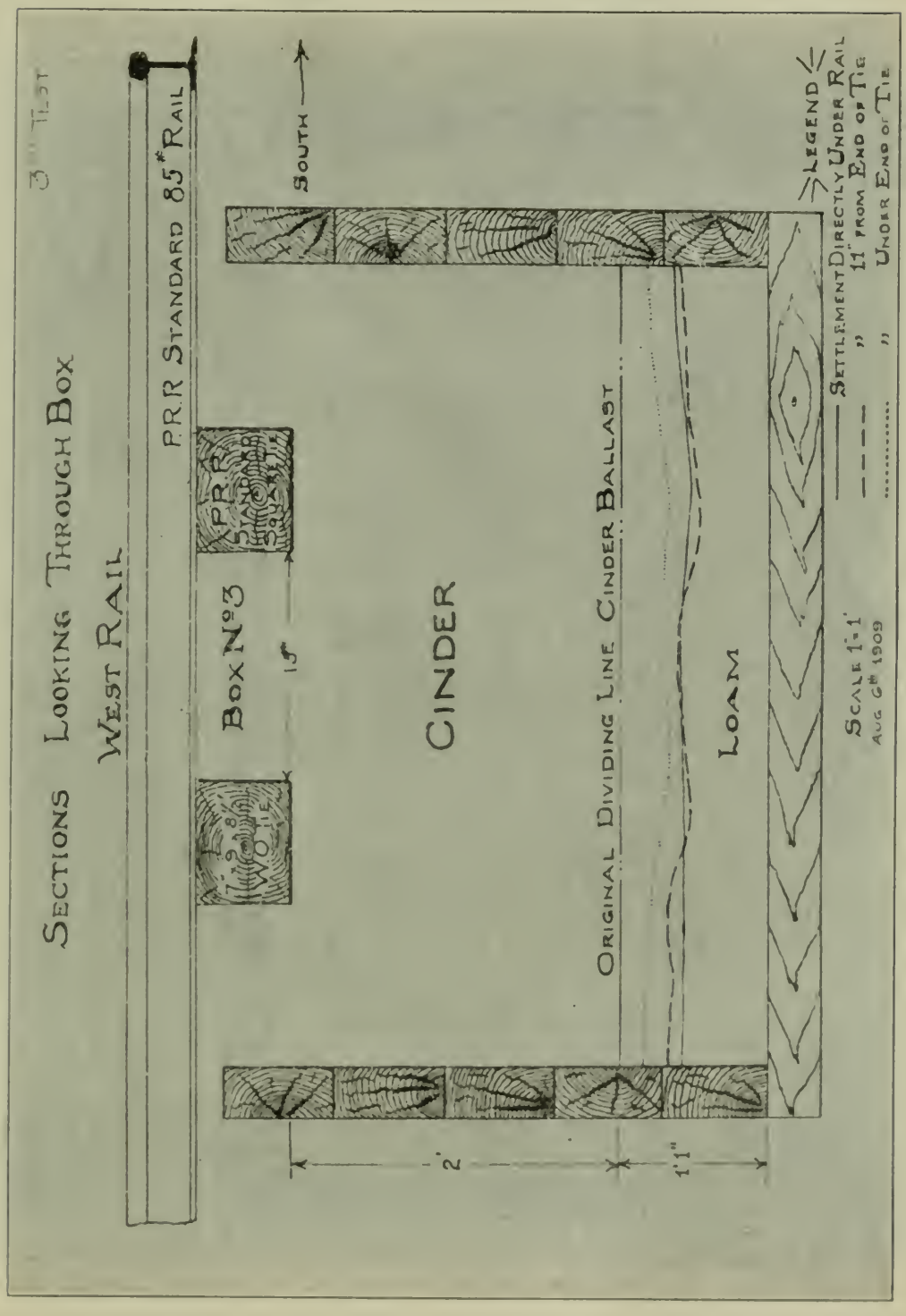

Test 3 - Box 3 - East Rail.
10" from end of Rail.

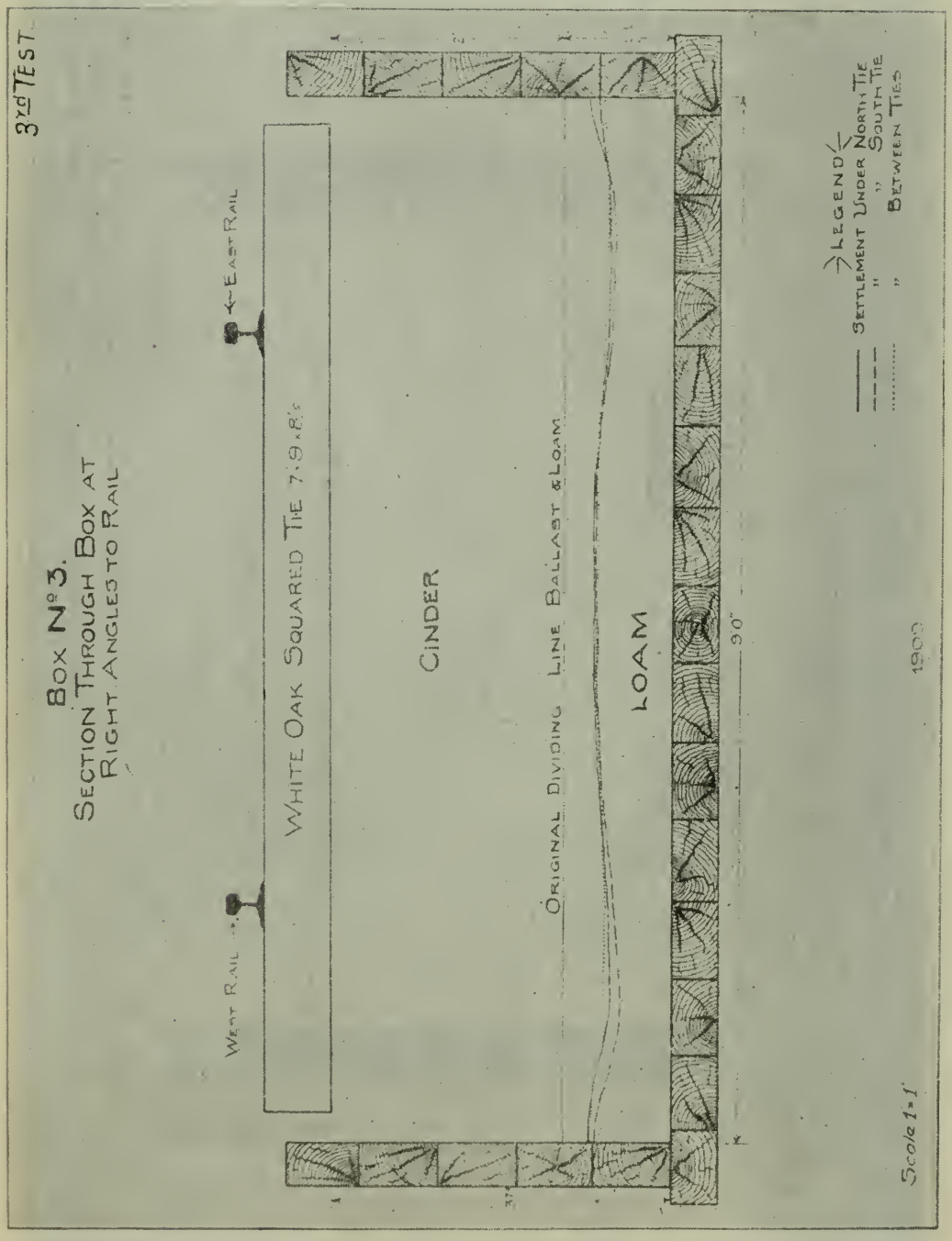

Test 3- Box 3- West Rail
10" from End of Rail

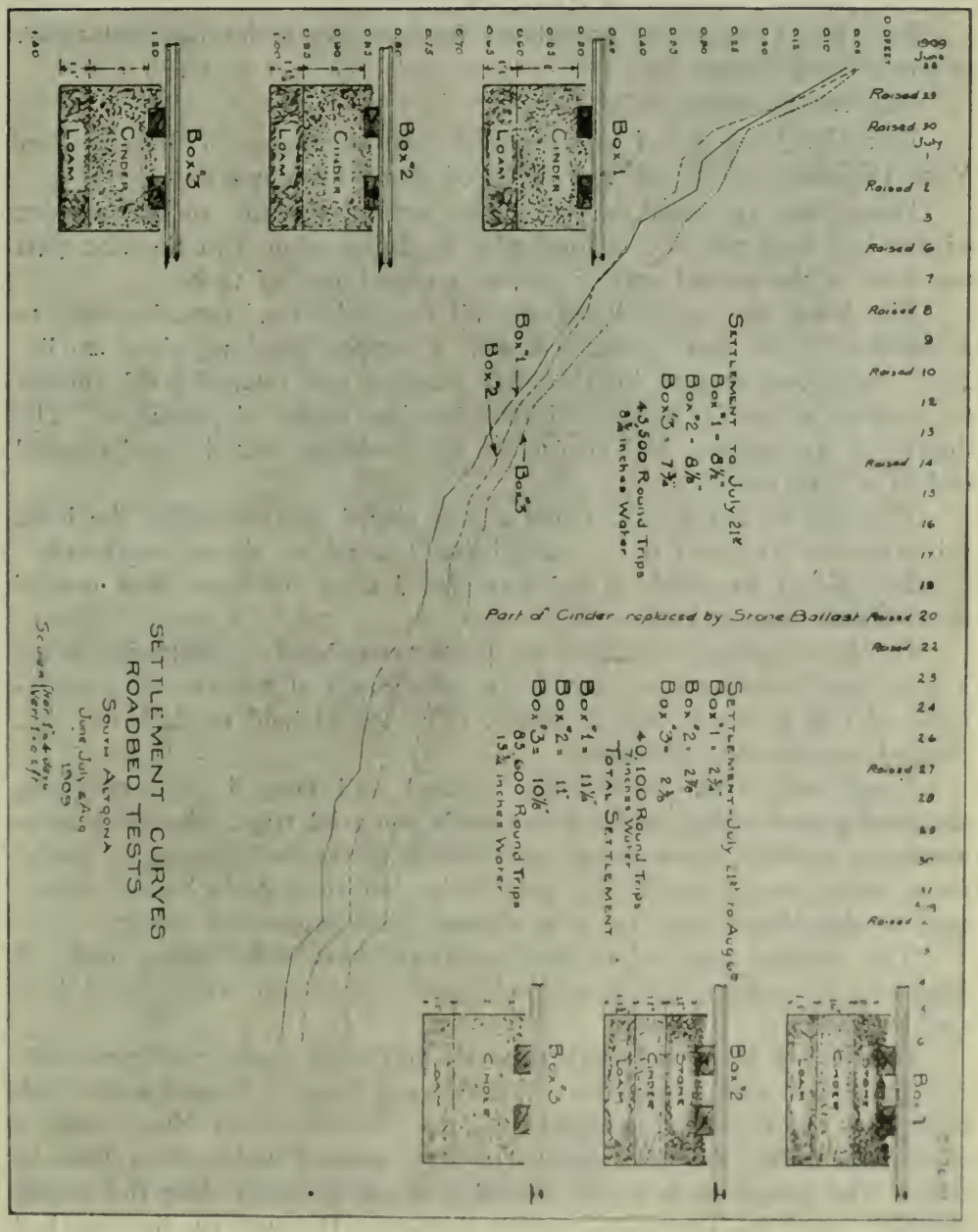

Test 3-Box 3-East Rail-Under Rail


Test 3- Box 3- West Rail- Under Rail


3rd Test
Sections Looking Through Box
East Rail
P.R.R. Standard 85# Rail
South
4½"
P.R.R. Standard Tie
Box No 3
15"
7"×9"×8'6" White Pine Tie
Cinder
Original Dividing Line Cinder Ballast
Loam
4' 10½"
Inside Length of Wood Test Box 9'0"
2'
1'1"
4½"
3'4"


SECTIONS LOOKING THROUGH BOX
WEST RAIL
P.R.R STANDARD 85# RAIL
BOX N°3
CINDER
ORIGINAL DIVIDING LINE CINDER BALLAST
LOAM
SOUTH
LEGEND
SETTLEMENT DIRECTLY UNDER RAIL
" 11' FROM END OF TIE
" UNDER END OF TIE
SCALE 1"-1'
AUG 6TH 1909
2'
1'1"


3rd Test
Box No 3.
Section Through Box at Right Angles to Rail
East Rail
West Rail
White Oak Squared Tie 7.9 x 8.5
Cinder
Original Dividing Line Ballast & Loam
Loam
30"
Legend
Settlement Under North Tie
" South Tie
" Between Ties
1900
Scale 1-1'


SETTLEMENT CURVES
ROADBED TESTS
SOUTH ARIZONA
June July & Aug
1909
Box 1
Box 2
Box 3
Cinder
Loam
Stone
Raised
Part of Cinder replaced by Stone Ballast
Box 1 - 11¼"
Box 2 - 11"
Box 3 - 10½"
83,600 Round Trips
15¼ Inches Water
Box 1 - 2¾"
Box 2 - 2⅞"
Box 3 - 2⅜"
40,100 Round Trips
5 Inches Water
Box 1 - 6½"
Box 2 - 6⅝"
Box 3 - 7¾"
43,500 Round Trips
8½ Inches Water

TEST NO. 4.

October 19 to December 3, 1909.

First Part.

MATERIAL IN BOXES.

Box No. 1—24 in. of granulated furnace slag under ties and 12 in. of sandy loam below.

Box No. 2—Same as box No. 1.

Box No. 3—24 in. of sandy gravel from Bonhampton Branch, New York Division, under ties, and 12 in. of sandy loam below.

Water was sprinkled on the boxes during the run to the amount of one-half inch per day, a total of 8 in. being applied in the first part and 6 in. in the second part of test, or a grand total of 14 in.

The loam was well forked and all lumps broken, spread evenly to a depth of 6 in., then compacted with a tamper weighing about 20 lbs. Each layer was treated in a similar manner and tamped hard enough to support a man's weight without leaving undue depressions. The degree of compactness was also tested by prodding with the unsharpened end of a lead pencil.

The slag in boxes Nos. 1 and 2 was placed carefully upon the loam sub-grade in layers of 6 in., each being tamped as above mentioned.

Box No. 3, in which gravel was placed upon the loam, was treated in a similar manner.

On the morning of October 16 the car completed 12 trial trips, when it was found necessary to shut down on account of the excessive settlement of slag in boxes Nos. 1 and 2. The gravel held much better, but showed considerable settlement.

Track was raised on October 18, and well tamped; the necessary slag and gravel added, and the car made ten trial trips, when it became necessary to shut down again and retamp boxes on account of settlement, when the car made fifty round trips before it again became necessary to shut down since the slag showed little supporting power.

The roadbed external to the boxes was very solid, being made of limestone screenings, which was subjected to constant wetting and load and had become very hard.

In order to allow the track to settle uniformly, water was constantly run upon the roadbed outside of the boxes from a three-fourths inch hose, and the ties kept pumping. As the slag in boxes Nos. 1 and 2 compacted under the ties, more slag was worked under from time to time. The gravel in box No. 3 held well—even better than the cinder similarly used in Test No. 3. On this day, October 19, the car had completed 735 round trips.

On October 21, the track was raised and the sprinkling of water on the boxes commenced, by means of a three-fourths inch garden hose attached to a graduated oil barrel.

The quantity of water put on each box per day was one-half inch,

one-fourth inch the first thing in the morning and another one-fourth inch at noon.

On October 23 the slag was developing supporting power, and on the 25th the track was secure enough to allow the continual running of the car day and night.

With a few interruptions it ran until November 17, when 45,561 round trips had been completed, the same number of round trips as were made in the first part of Test No. 3.

The settlement for the first part of the test up to November 17 was as follows: Box No. 1, 12½ in.; box No. 2, 13½ in., and box No. 3, 8⅝ in.

The following table gives some idea of the relative compressibility of the slag and gravel:

Amount of Material.

	Put in at Beginning.	Added to November 16.	Per Cent. Added.
Box No. 1—Slag	156 cu. ft.	105 cu. ft.	67.3
Box No. 2—Slag	147 cu. ft.	126 cu. ft.	85.7
Box No. 3—Gravel	108 cu. ft.	39 cu. ft.	36.1

Note.—Measurements were made of material in small quantities and when material was loose, before being placed and packed in boxes.

Second Part.

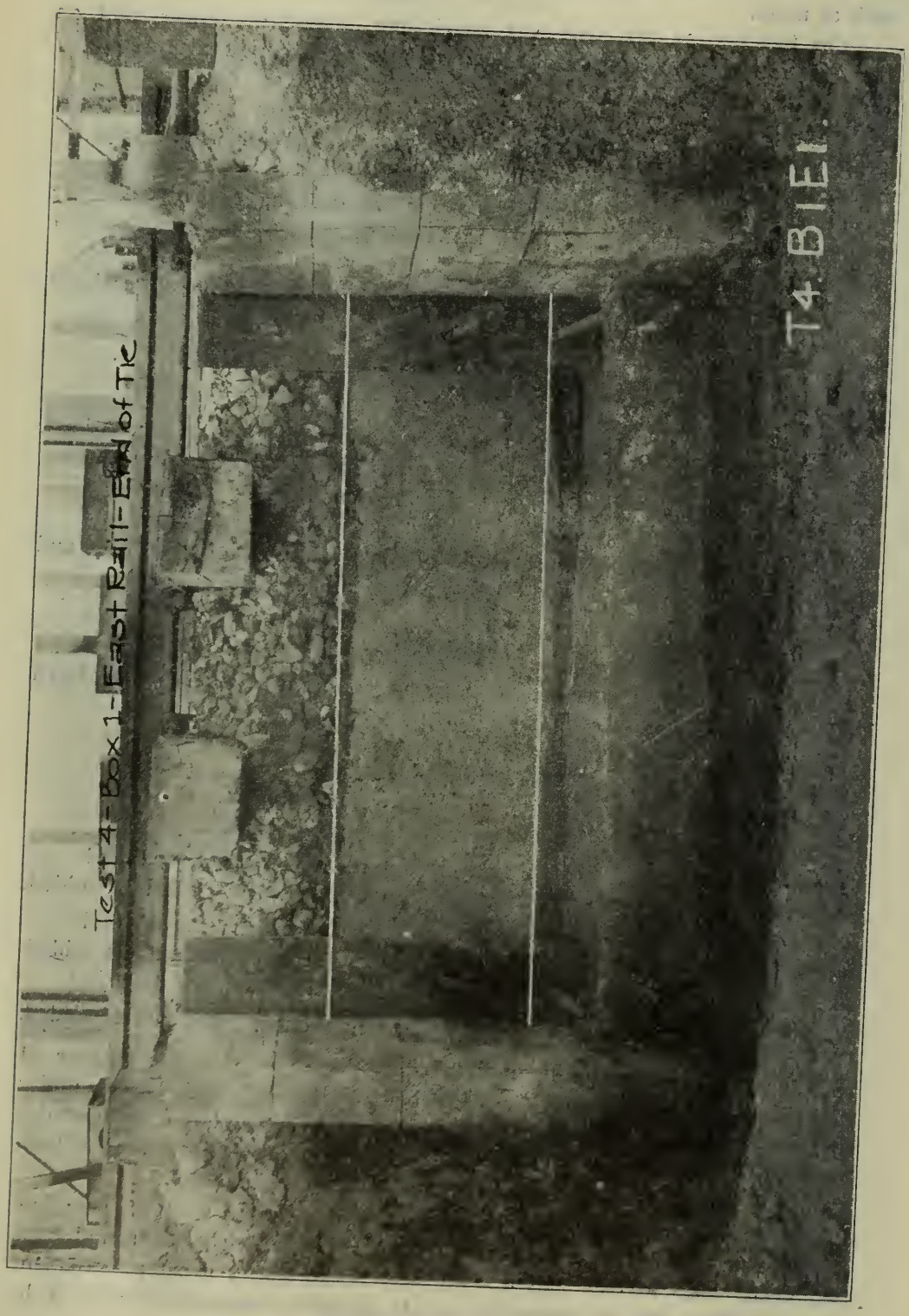
On November 17 some of the slag and part of the gravel was replaced by trap rock ballast, as follows:

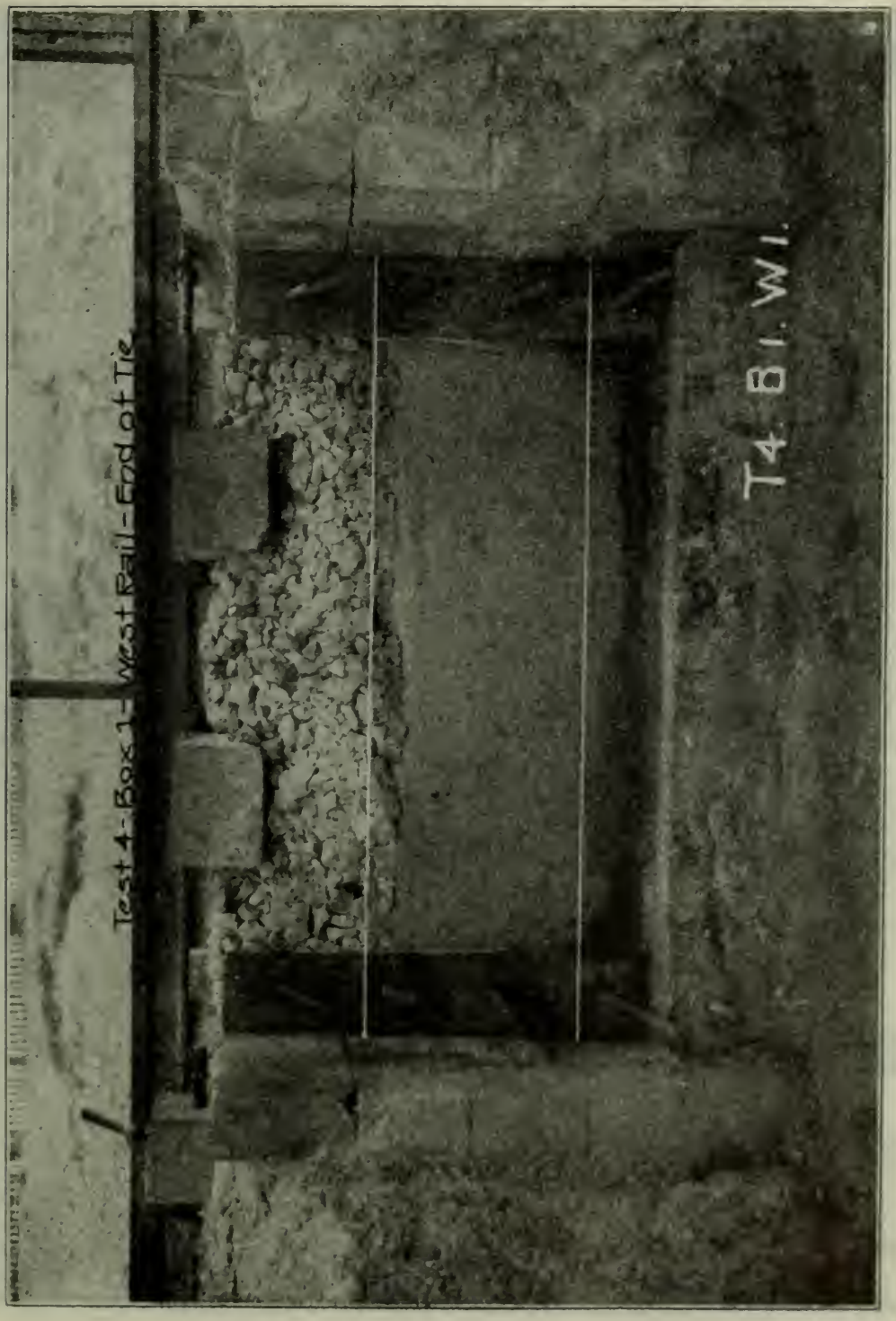
Statement of Conditions.

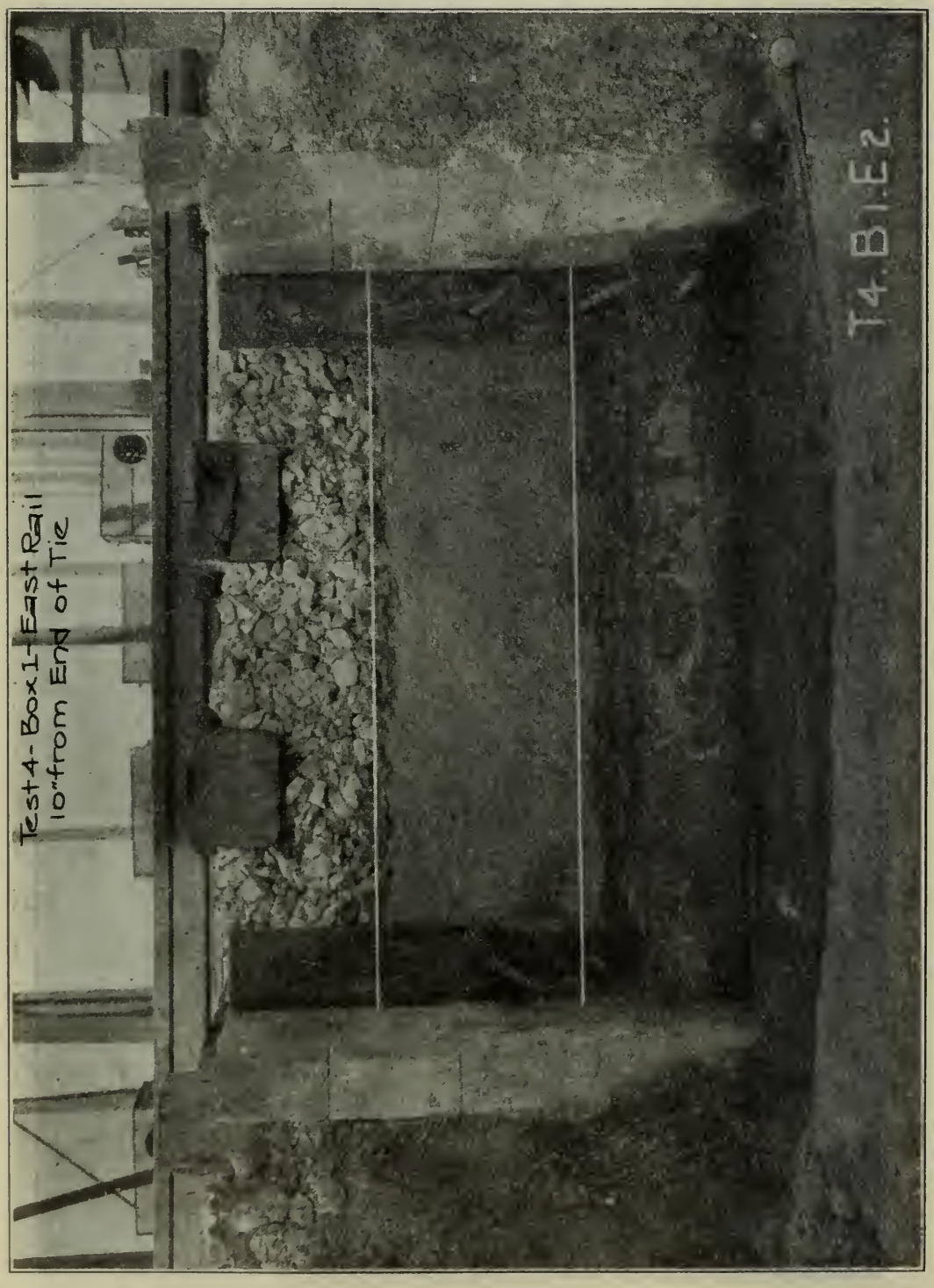
First part, 45,561 trips.		Second part, 40,060 trips.
12 in. of loam 24 in. of slag	Box No. 1	8 in. of slag removed and 8 in. of trap rock ballast added.
Same as Box No. 1	Box No. 2	12 in. of slag removed and 12 in. of trap rock ballast added.
24 in. of loam 24 in. of gravel	Box No. 3	12 in. of gravel removed and 12 in. of trap rock ballast added.

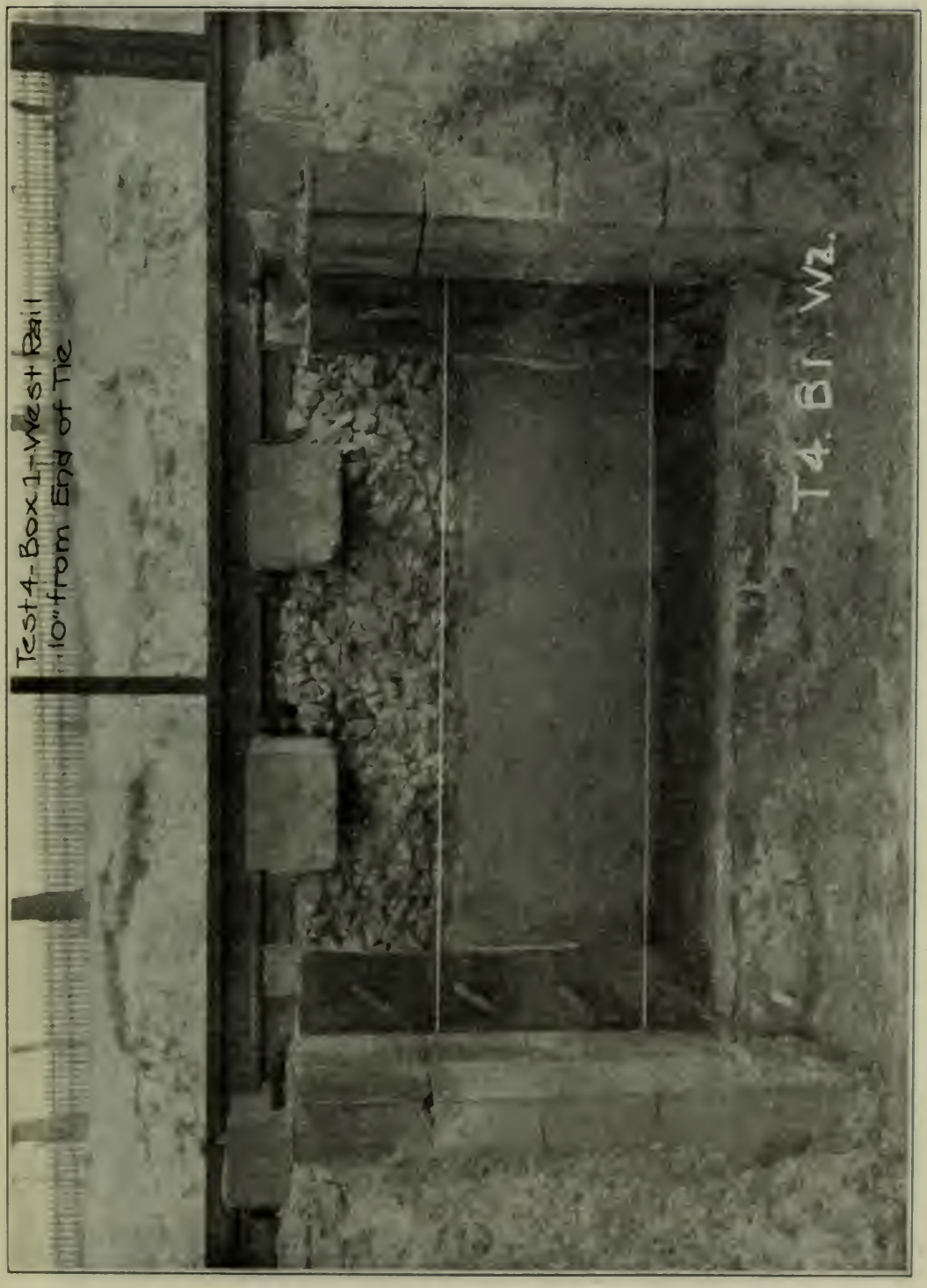
The stone was carefully added to the boxes so that the surface of the sub-ballast should not be disturbed. The slag and gravel under the ties broke off in pieces as large as one's head, and did not crumble on being dropped upon the ground. Picks were used to loosen both slag and gravel for removal by shovels.

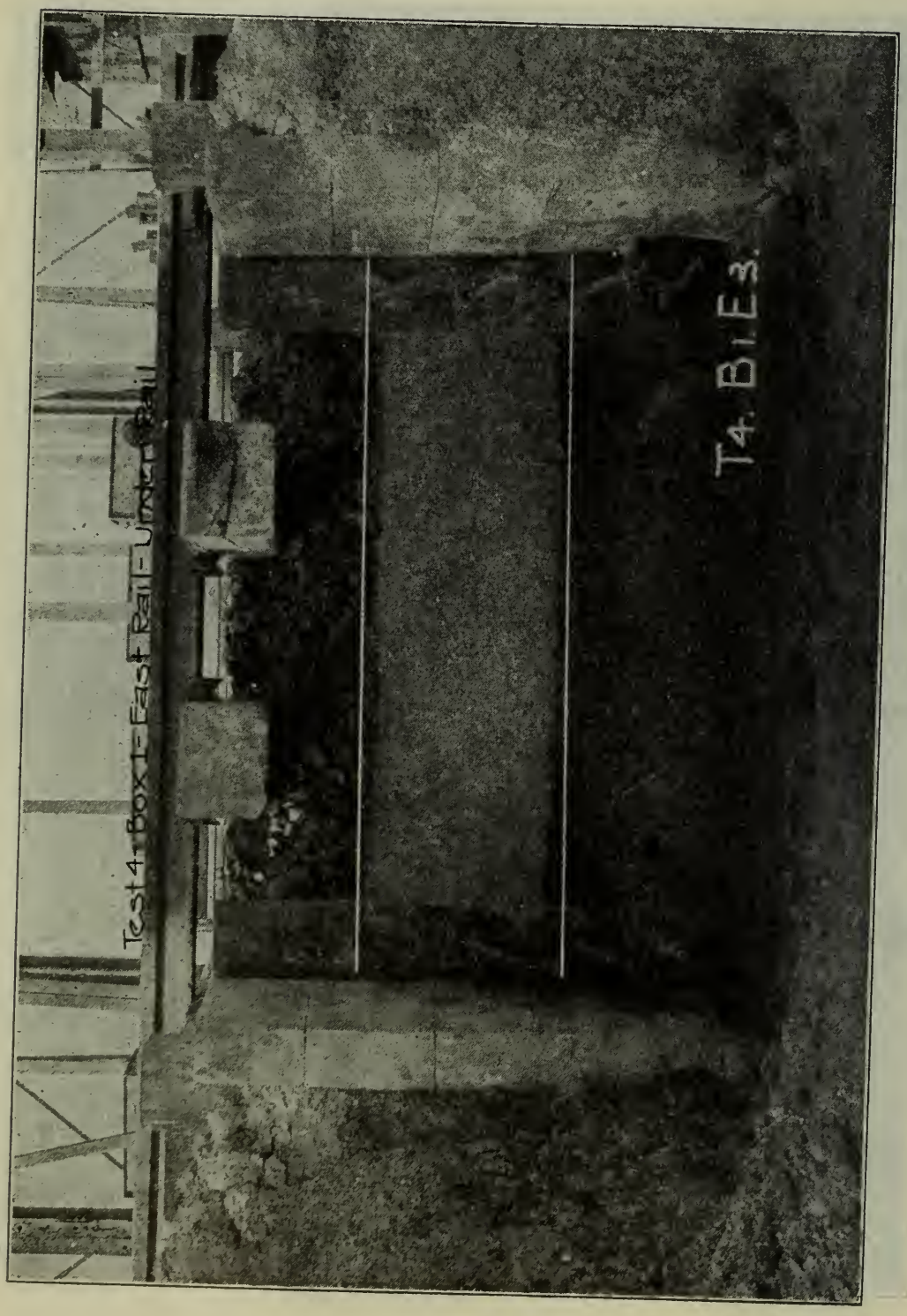
Nothing unusual was remarked during the second part of Test No. 4, which was finished on December 3, after a total of 85,621 round trips had been made for the entire test. The curve shows greater settlement than for Test No. 3, probably due to greater compressibility of sub-ballast, except in the gravel.

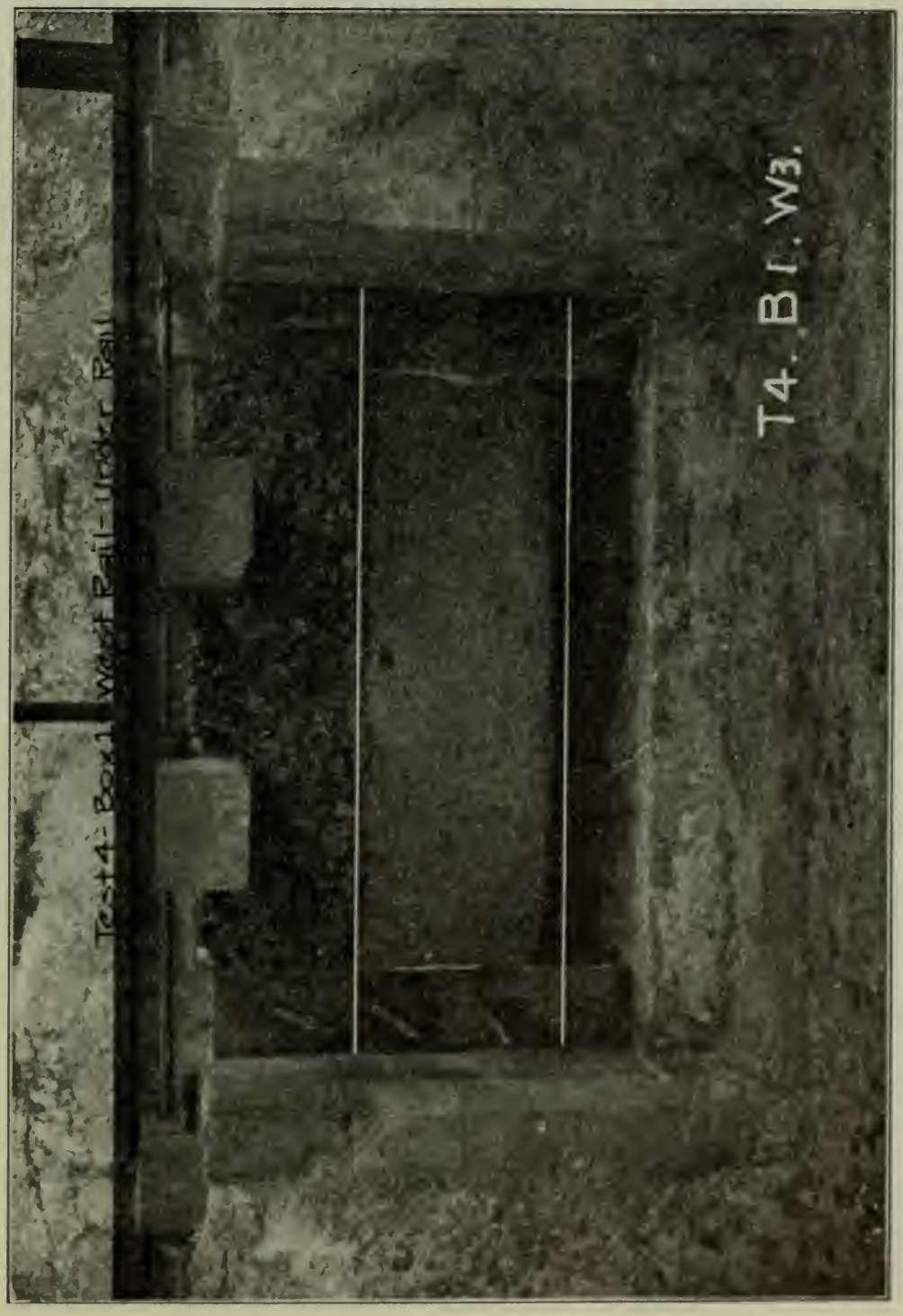

Test 4 - Box 1 - East Rail - End of Tie
T4. B1E1.

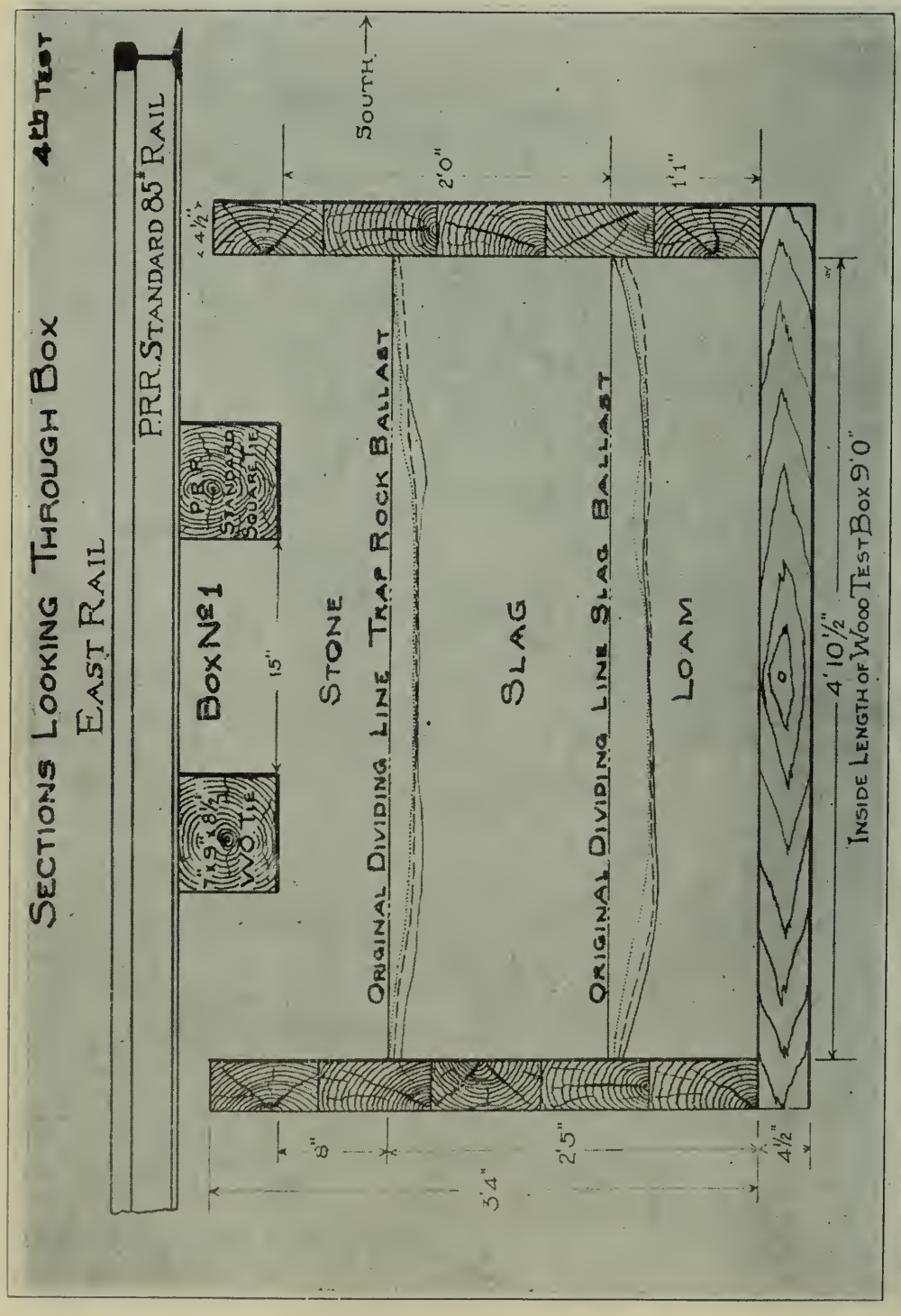

Test 4 - Box 1 - West Rail - End of Tie
T4. B1. W1.

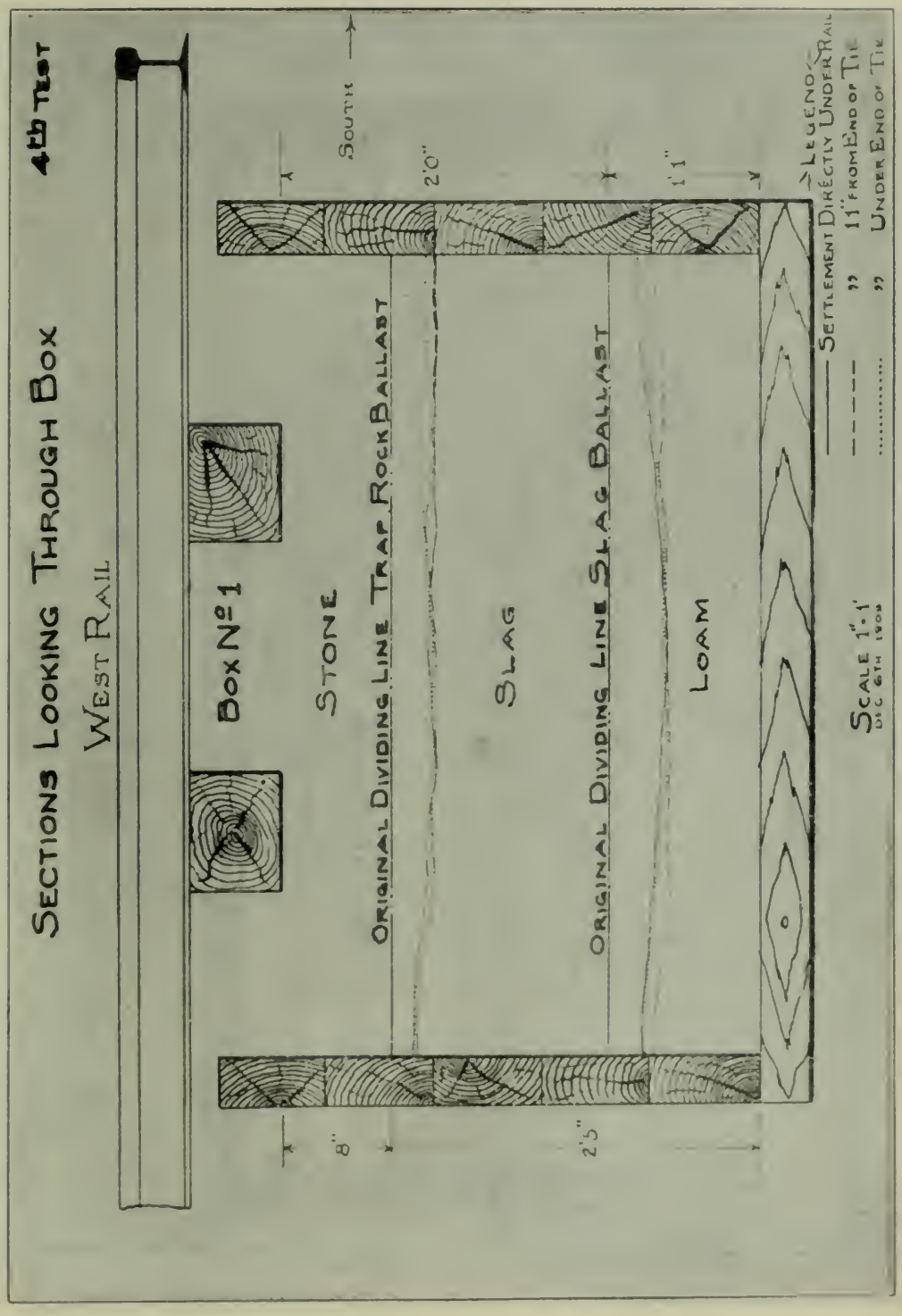

Test 4- Box 1- East Rail
10" from End of Tie
T4. B1. E2.

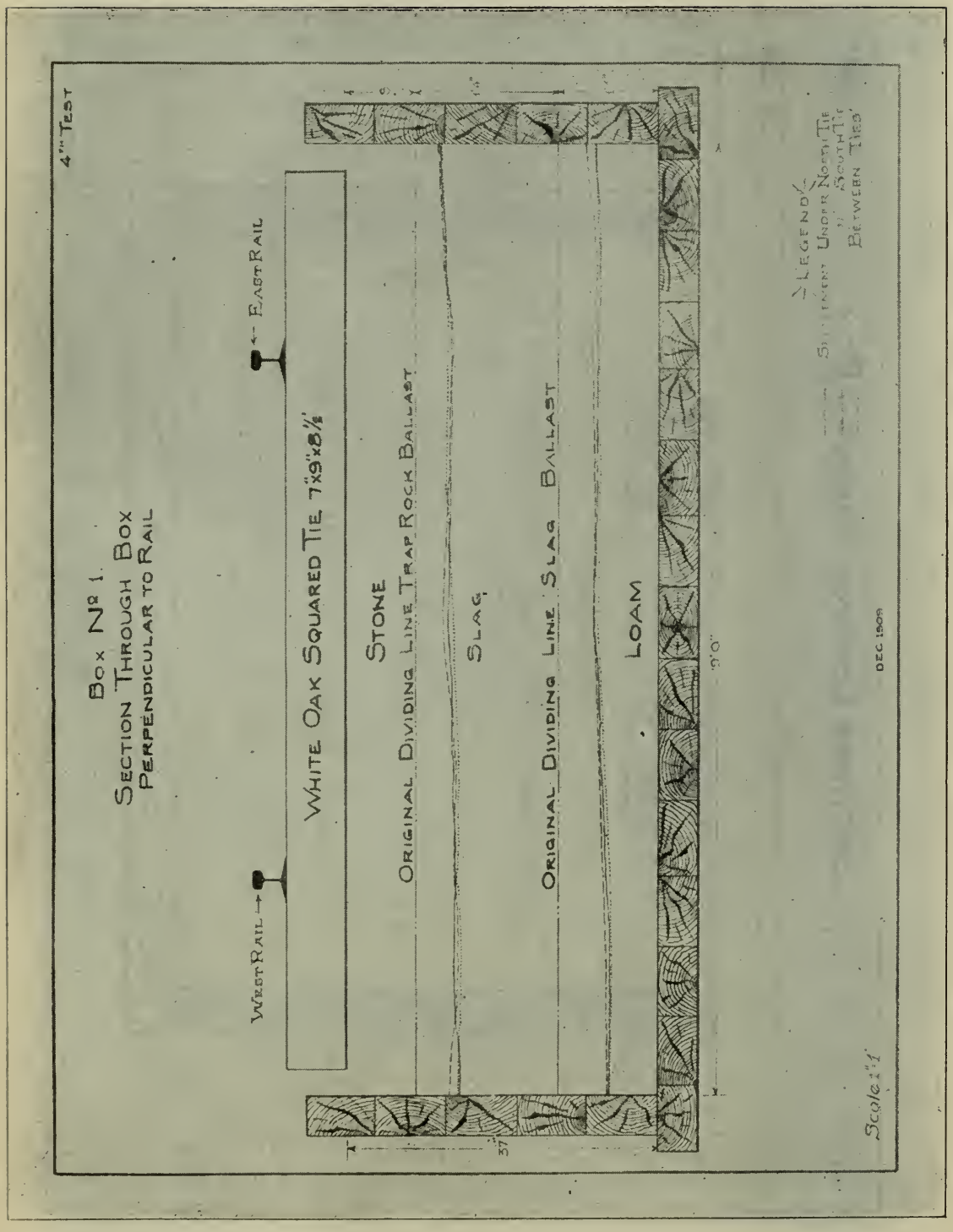

Test 4-Box 1-West Rail
10" from End of Tie
T4 Br. W2.

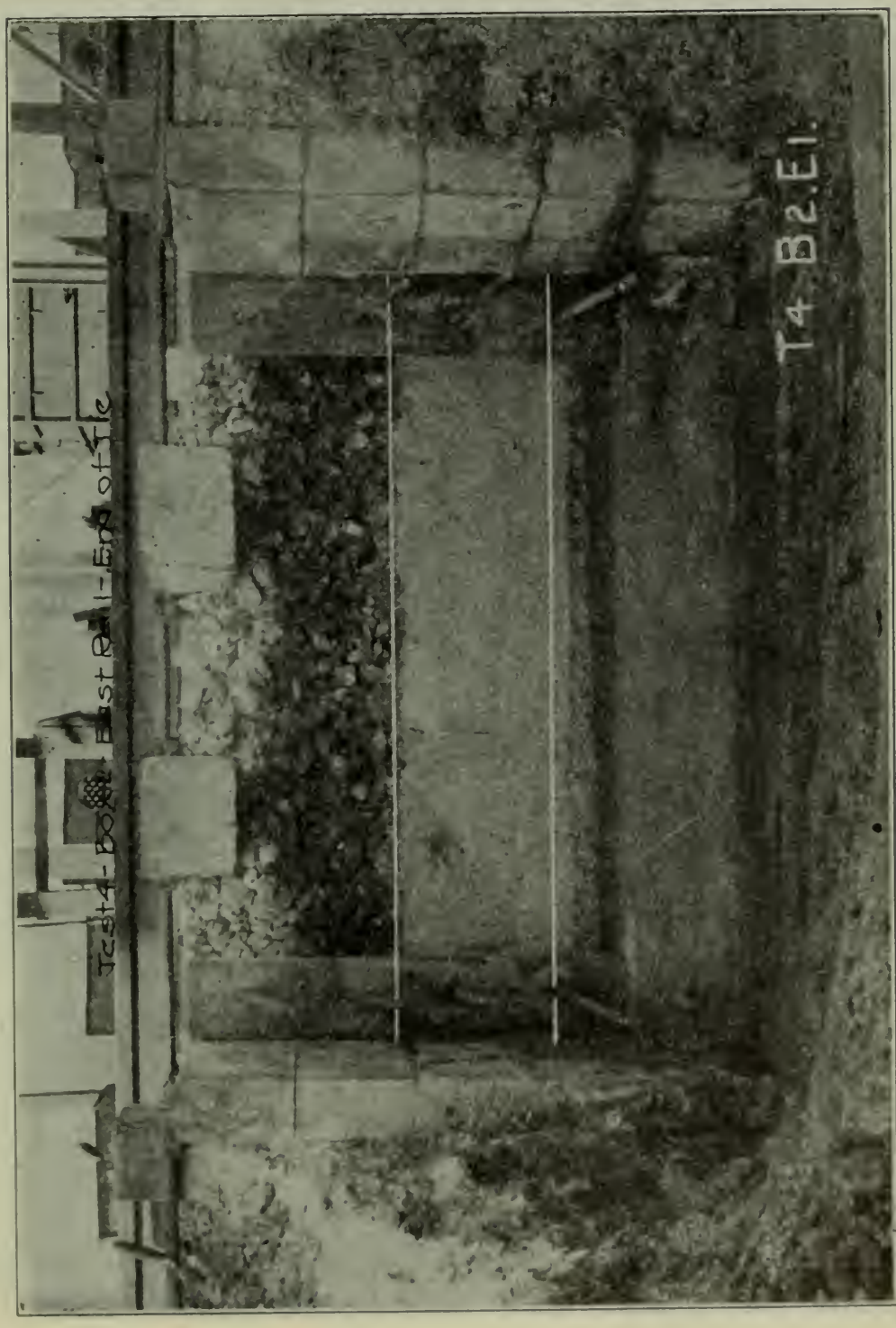

Test 4 - Box 1 - East Rail - Under Rail
T4. B1. E3.

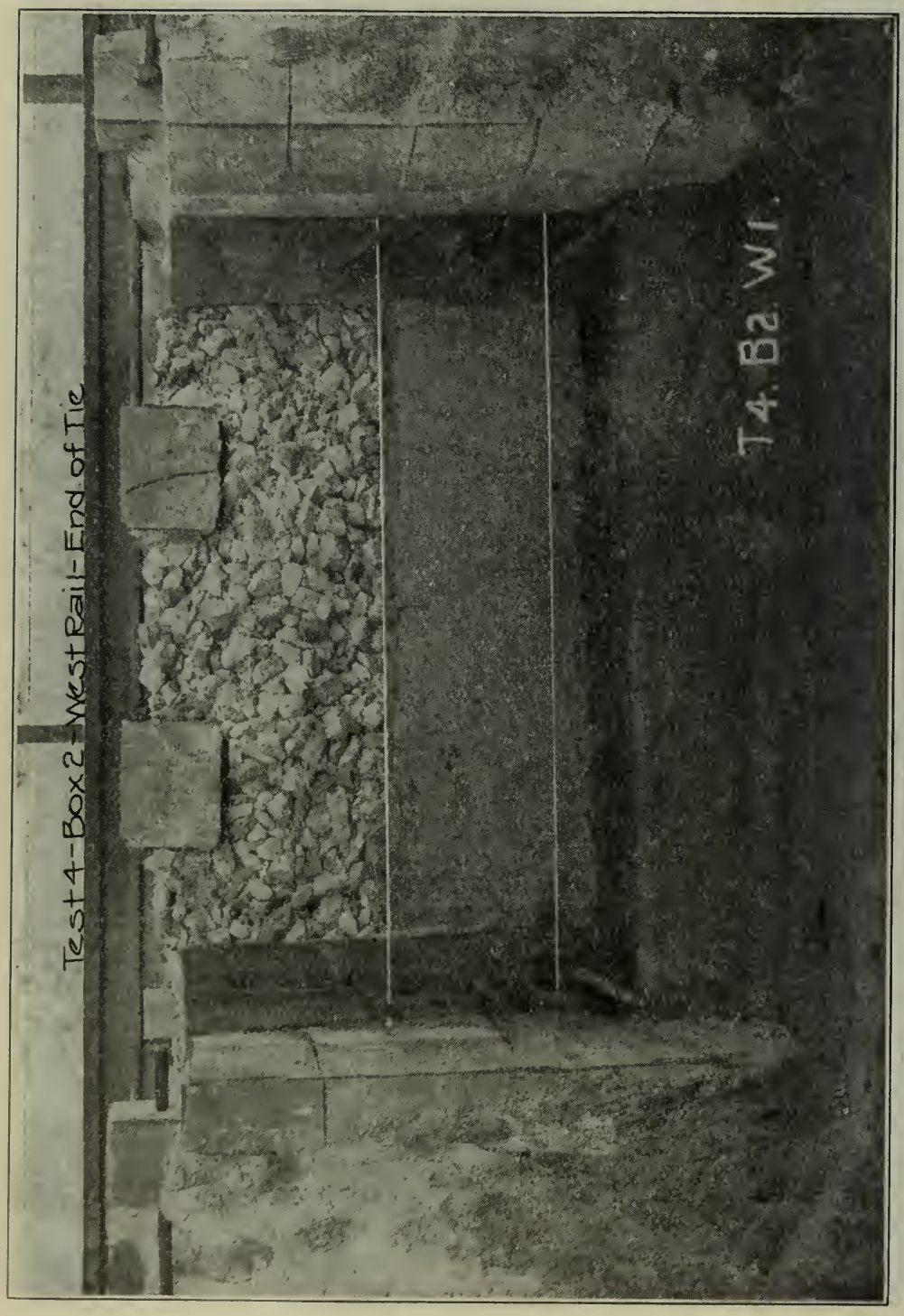

T4. Br. W3.
Test 4: Box 1 West Rail-Under Rail

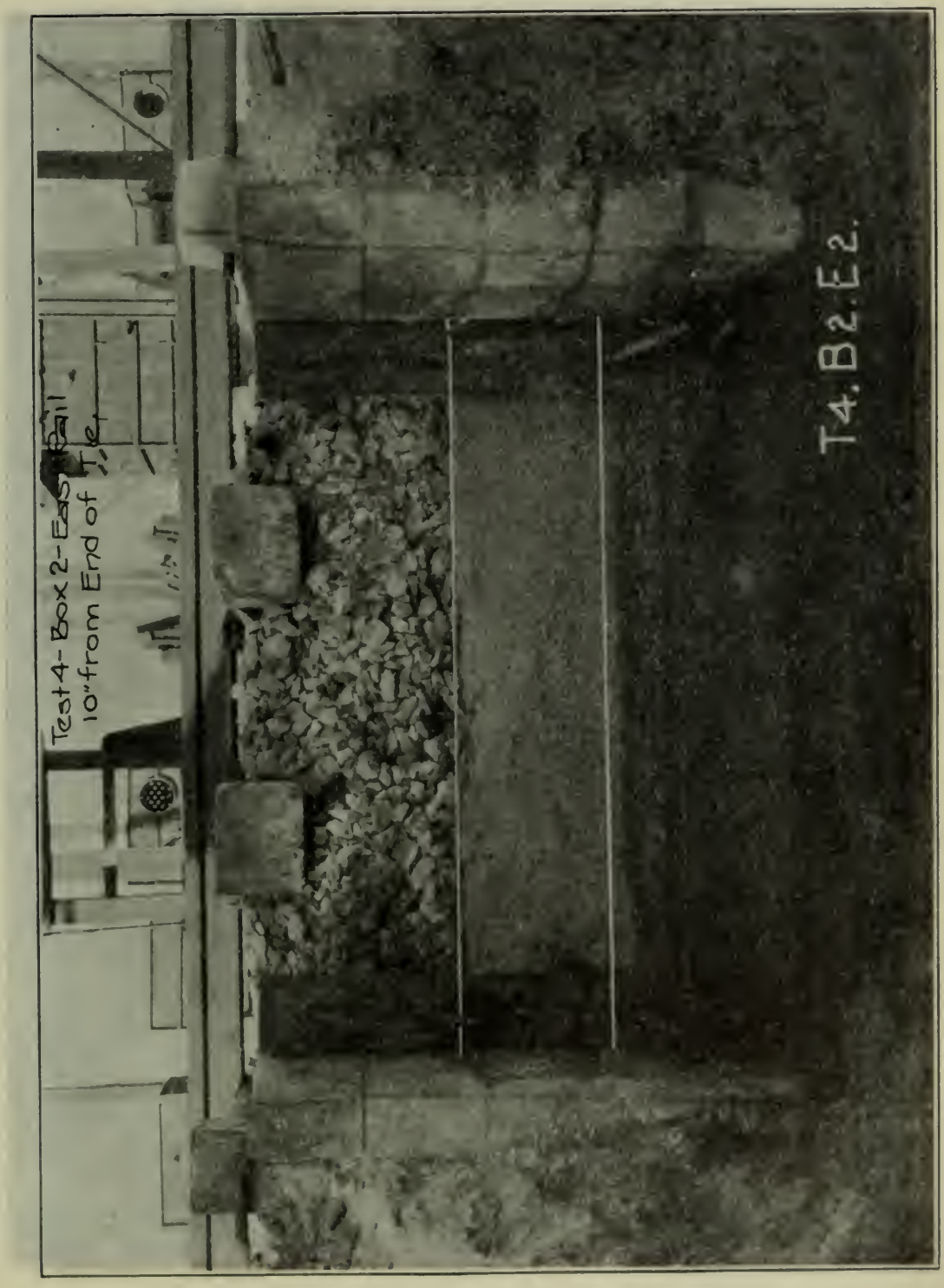

SECTIONS LOOKING THROUGH BOX
4th TEST
EAST RAIL
P.R.R. STANDARD 85# RAIL
BOX Nº1
STONE
SLAG
LOAM
ORIGINAL DIVIDING LINE TRAP ROCK BALLAST
ORIGINAL DIVIDING LINE SLAG BALLAST
SOUTH
15"
2'0"
1'1"
8"
2'5"
3'4"
4½"
4'10½"
INSIDE LENGTH OF WOOD TEST BOX 9'0"

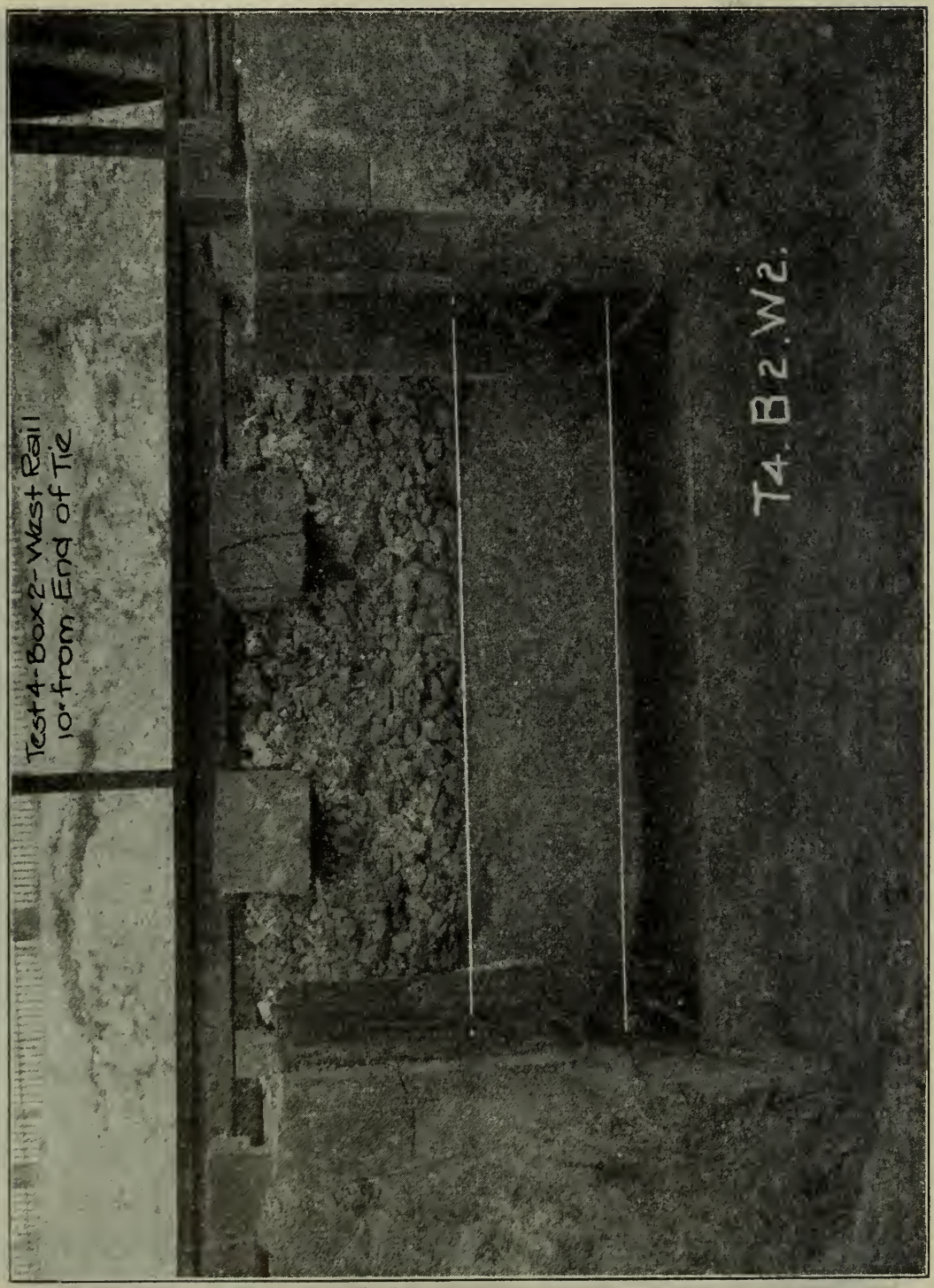

SECTIONS LOOKING THROUGH BOX
4th TEST
WEST RAIL
BOX Nº 1
STONE
SLAG
LOAM
ORIGINAL DIVIDING LINE TRAP ROCK BALLAST
ORIGINAL DIVIDING LINE SLAG BALLAST
SOUTH
2'0"
1'1"
8"
2'5"
LEGEND
SETTLEMENT DIRECTLY UNDER RAIL
" 11" FROM END OF TIE
" UNDER END OF TIE
SCALE 1"-1'
DEC 6TH 1905

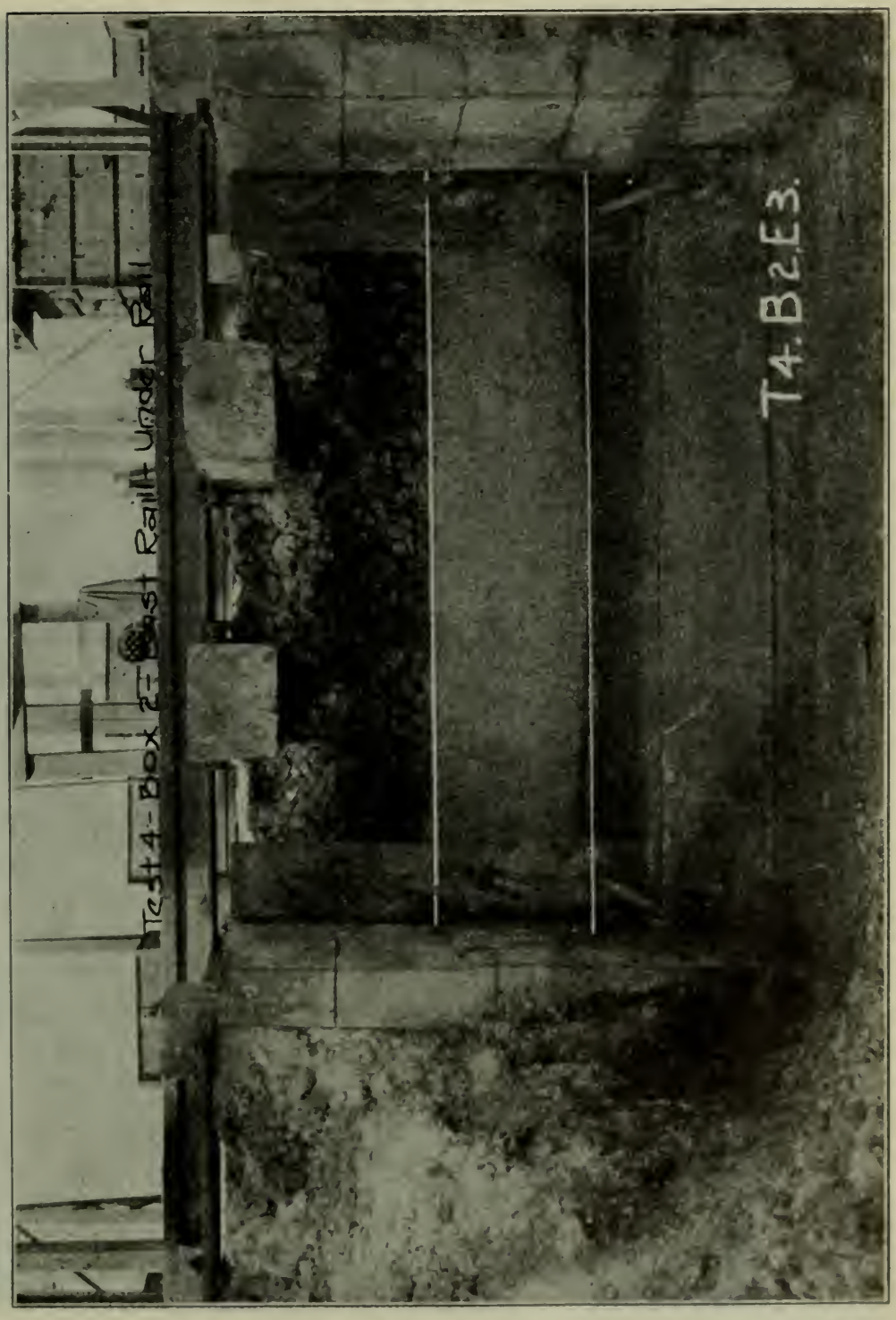

4" Test
Box No 1.
Section Through Box
Perpendicular to Rail
West Rail
East Rail
White Oak Squared Tie 7"x9"x8½'
Stone
Original Dividing Line Trap Rock Ballast
Slag
Original Dividing Line Slag Ballast
Loam
3'0"
37"
Legend
Under North Tie
South Tie
Between Ties
Scale 1"
Dec. 1909

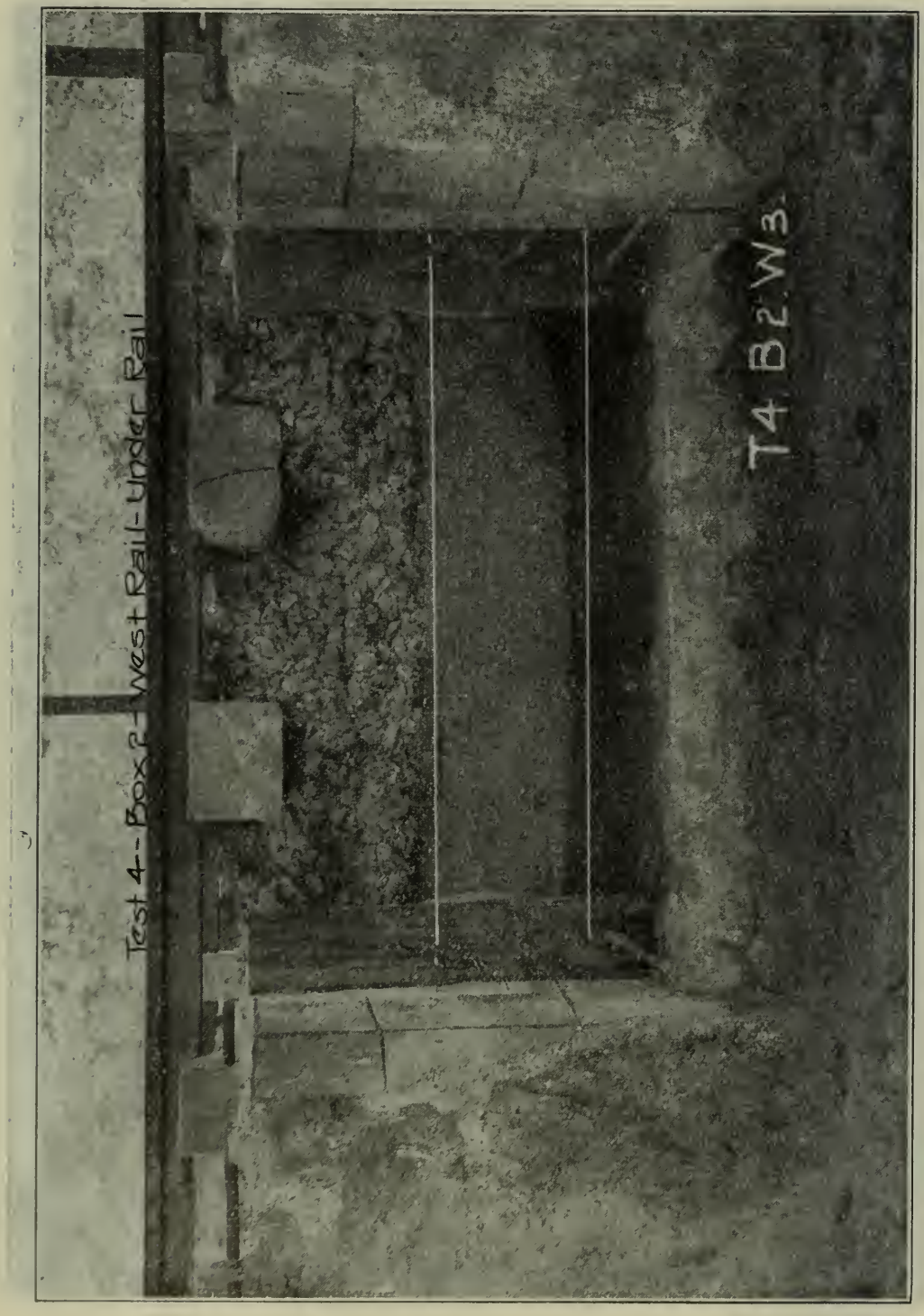

T4. B2. E1.

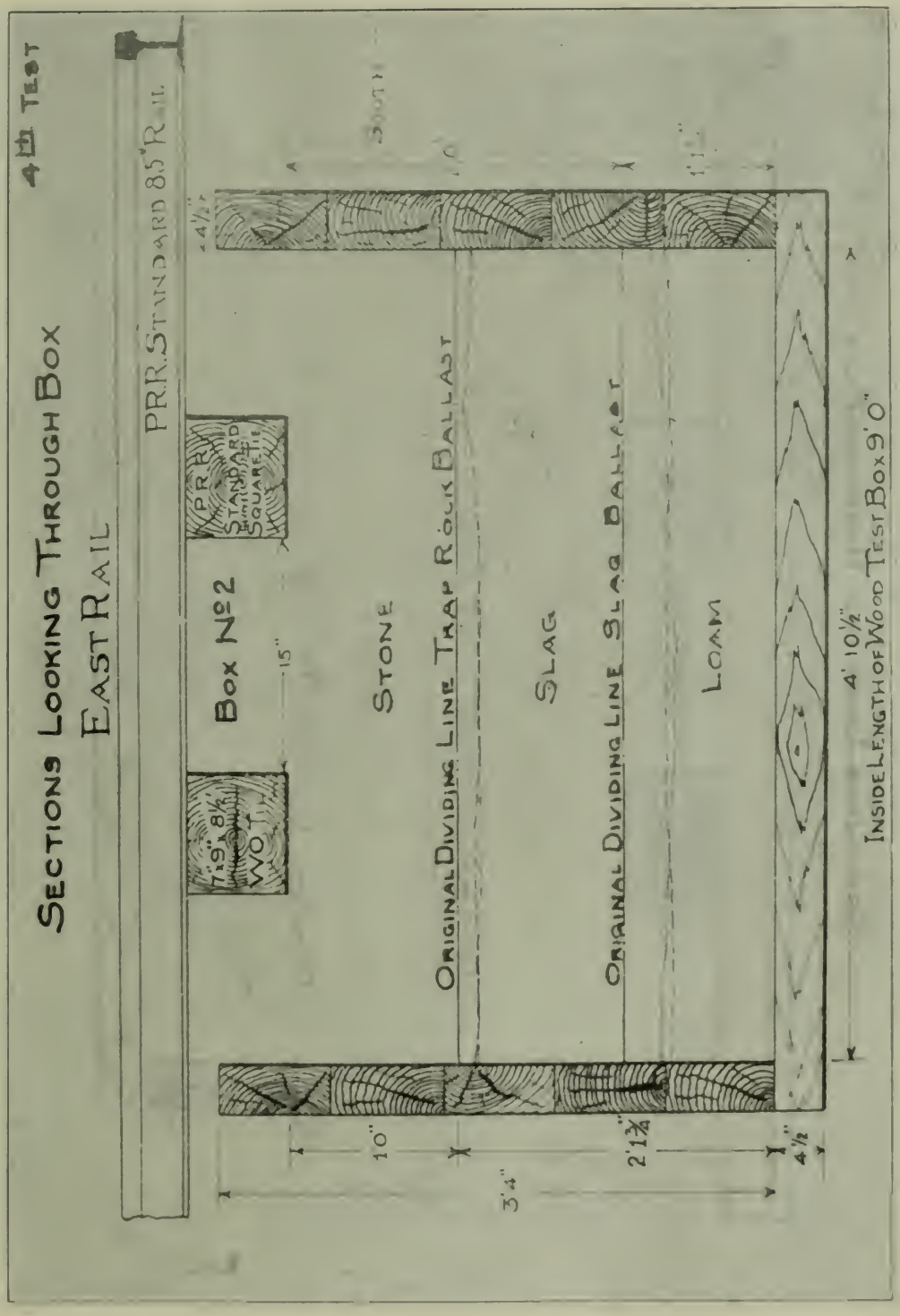

Test 4-Box 2-West Rail-End of Tie
T4. B2. W.r.

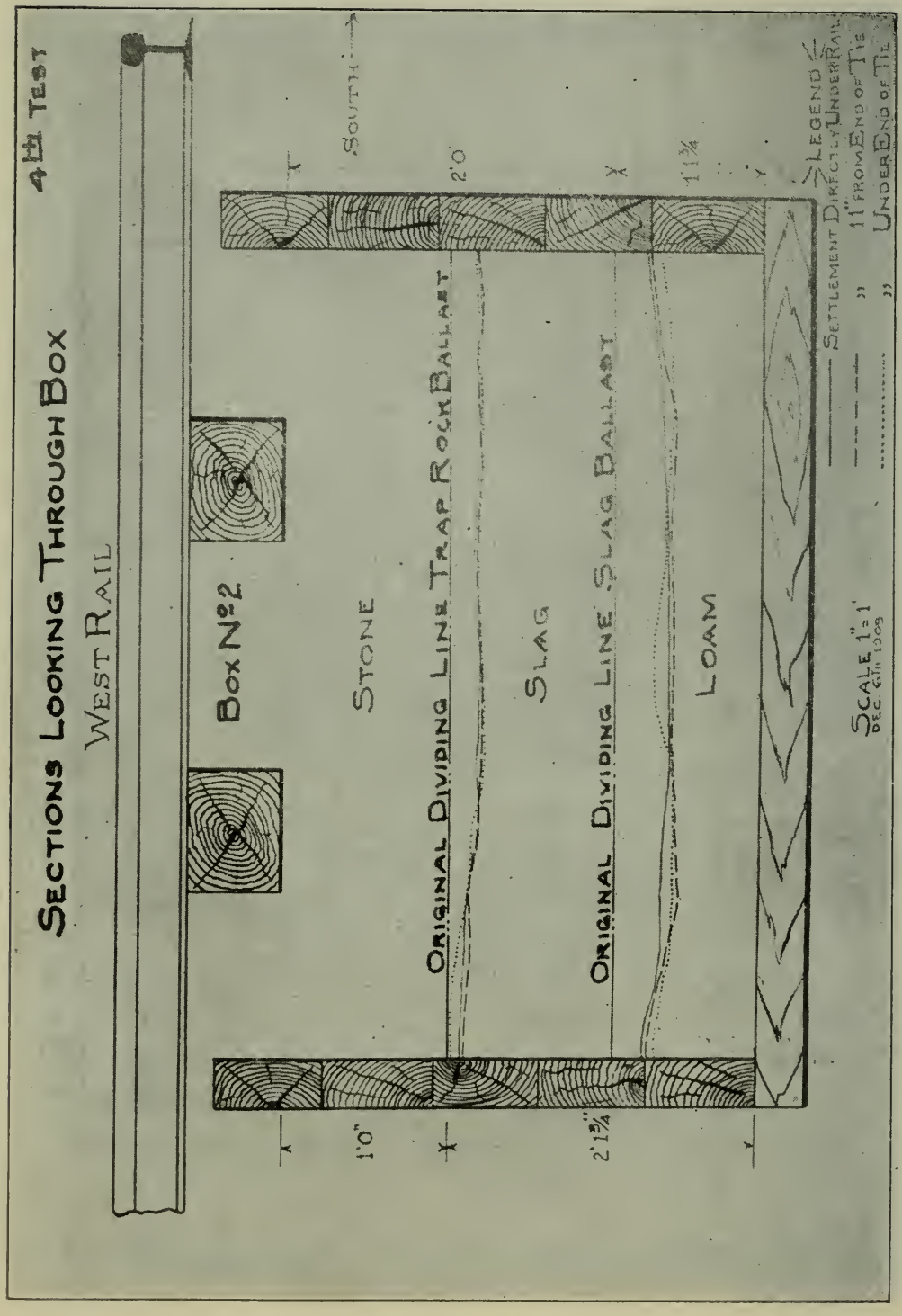

Test 4- Box 2- East Rail
10" from End of Tie
T4. B2. E2.

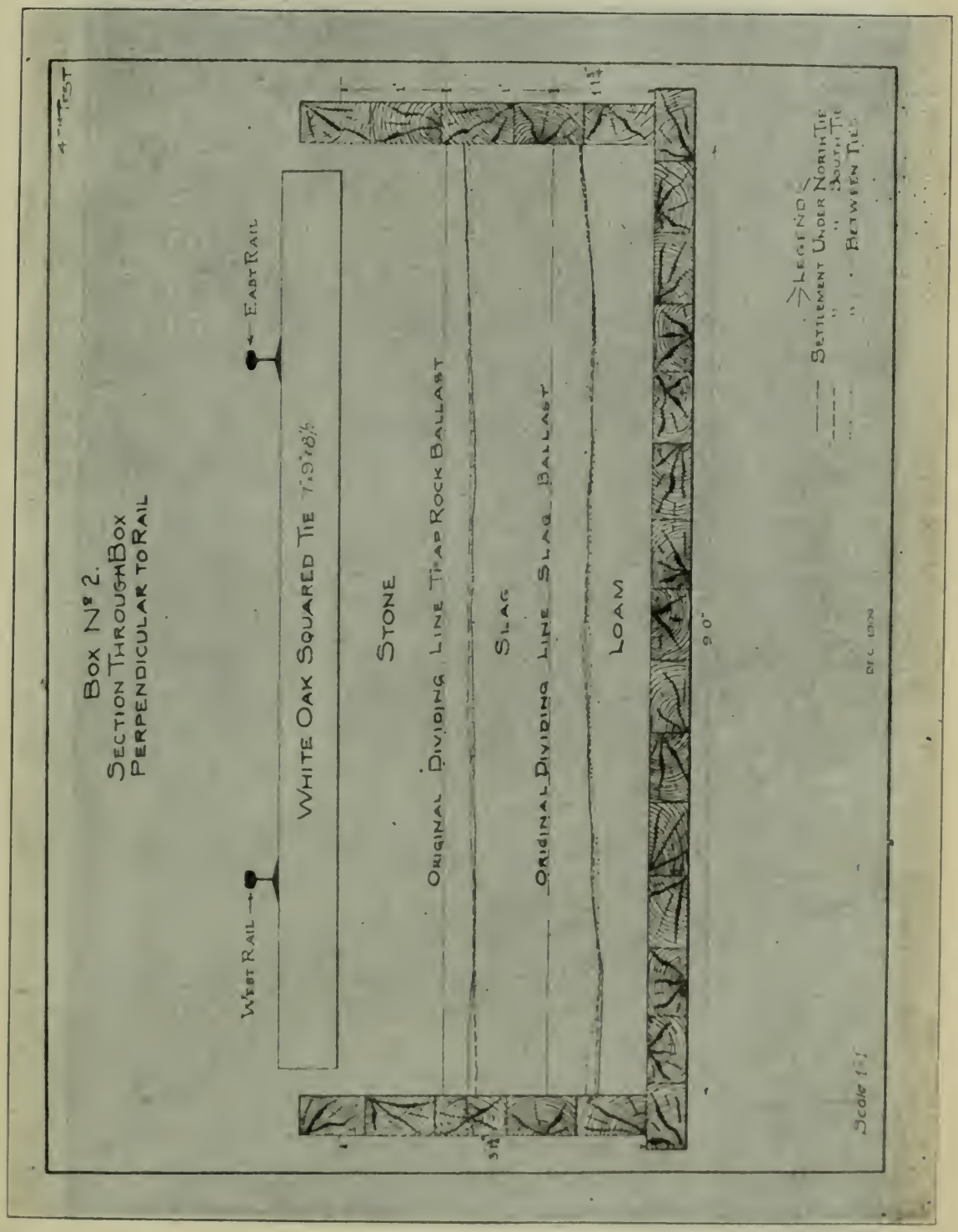

Test 4-Box 2-West Rail
10" from End of Tie
T4. B2. W2.

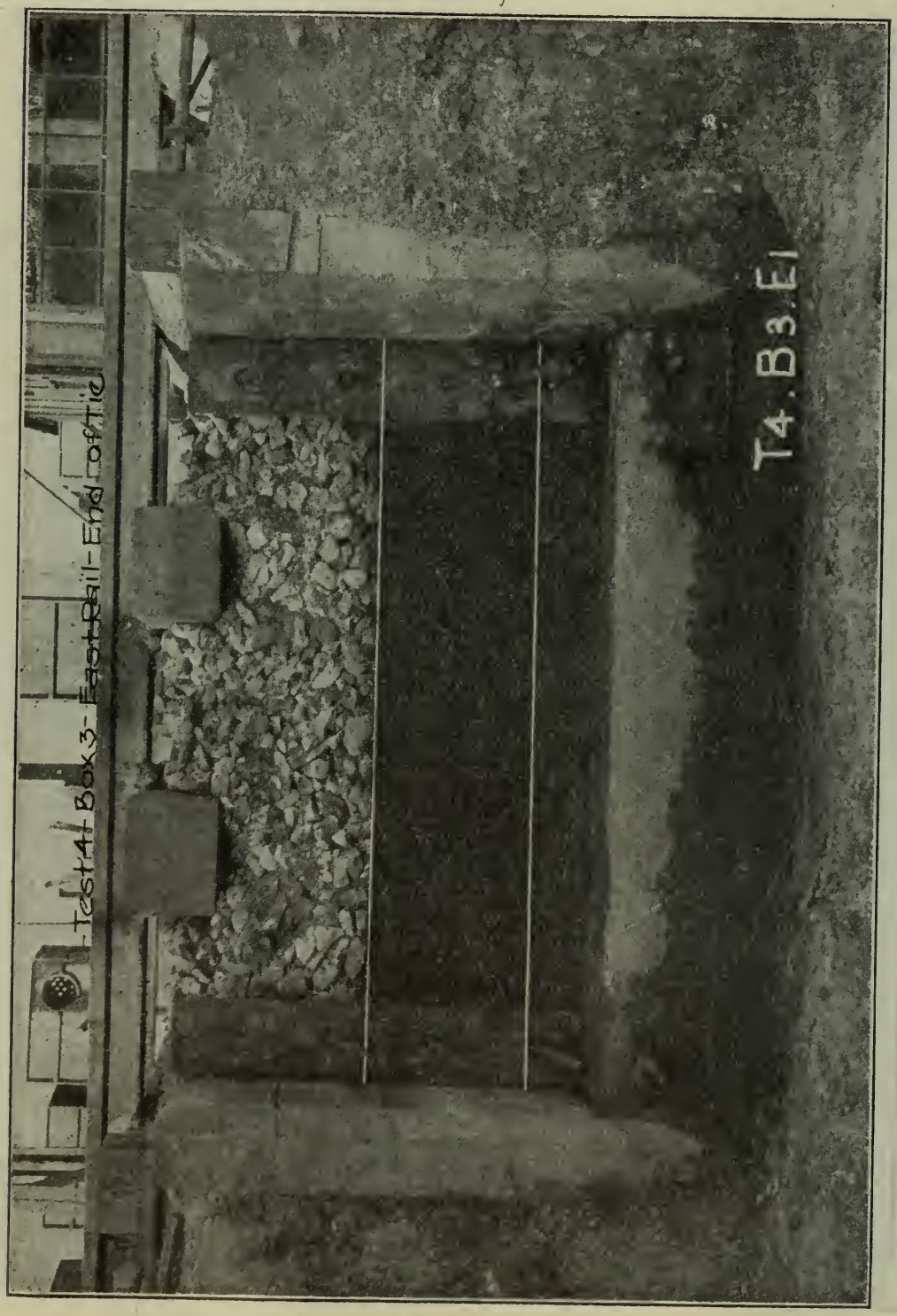

T4. B2. E3.
Test 4 - Box 2 - East Rail Under Rail

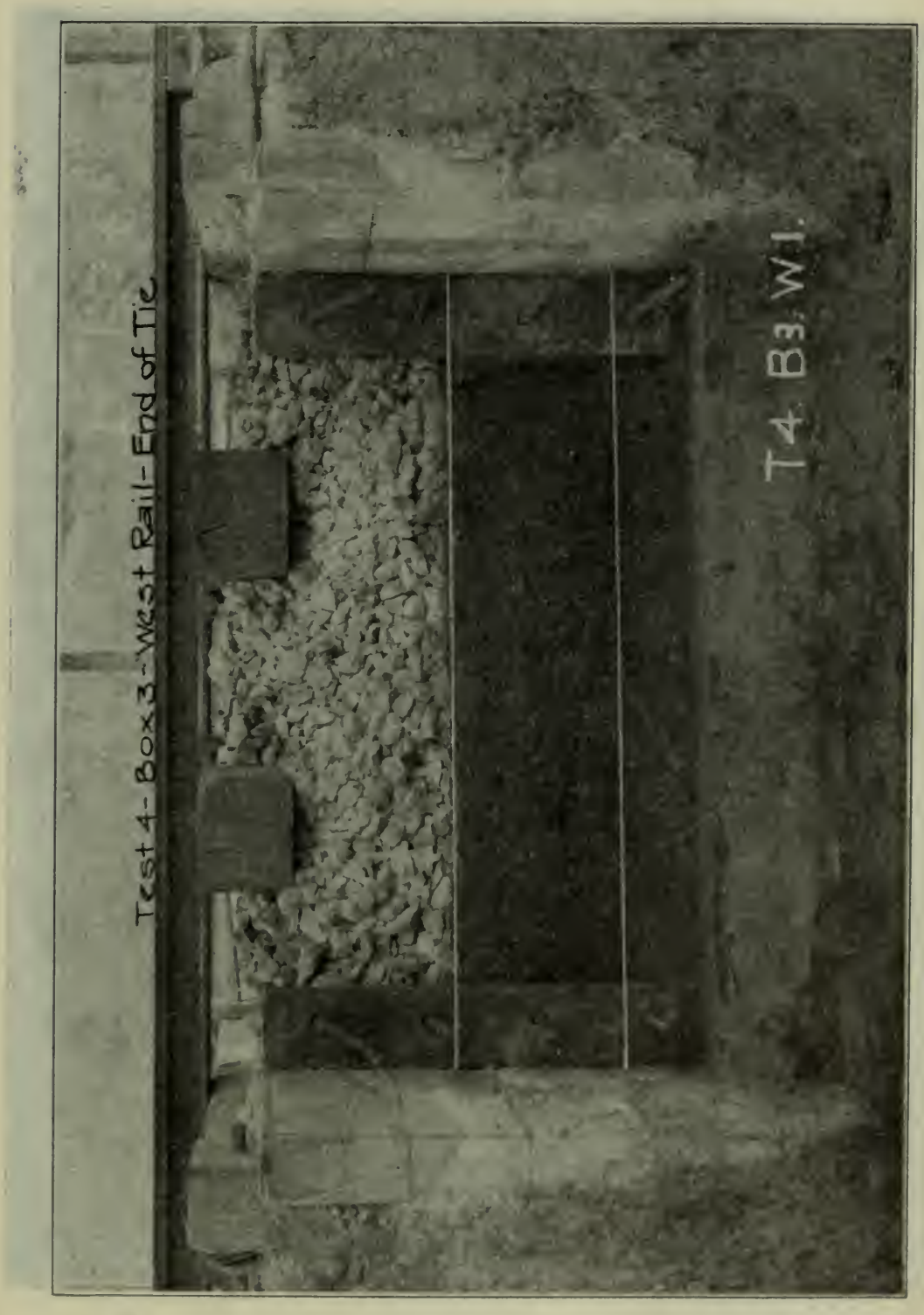

Test 4 - Box 2 - West Rail - Under Rail
T4 B2 W3.

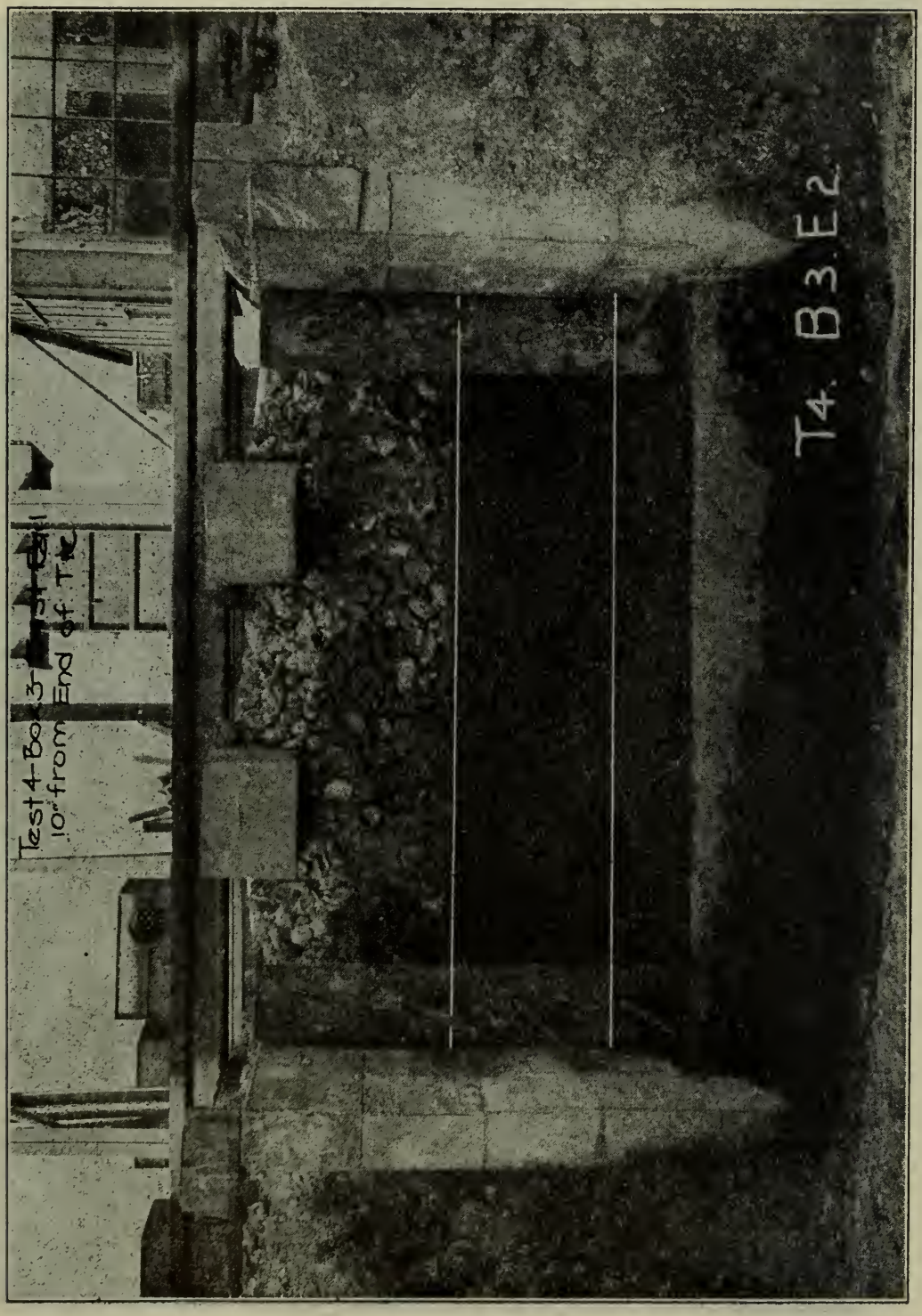

4th Test
Sections Looking Through Box
East Rail
PRR. Standard 85 lb. Rail
Box No 2
PRR Standard Square
15"
Stone
Slag
Loam
Original Dividing Line Trap Rock Ballast
Original Dividing Line Slag Ballast
10"
3'4"
2'1¾"
4½"
4' 10½"
Inside Length of Wood Test Box 9' 0"

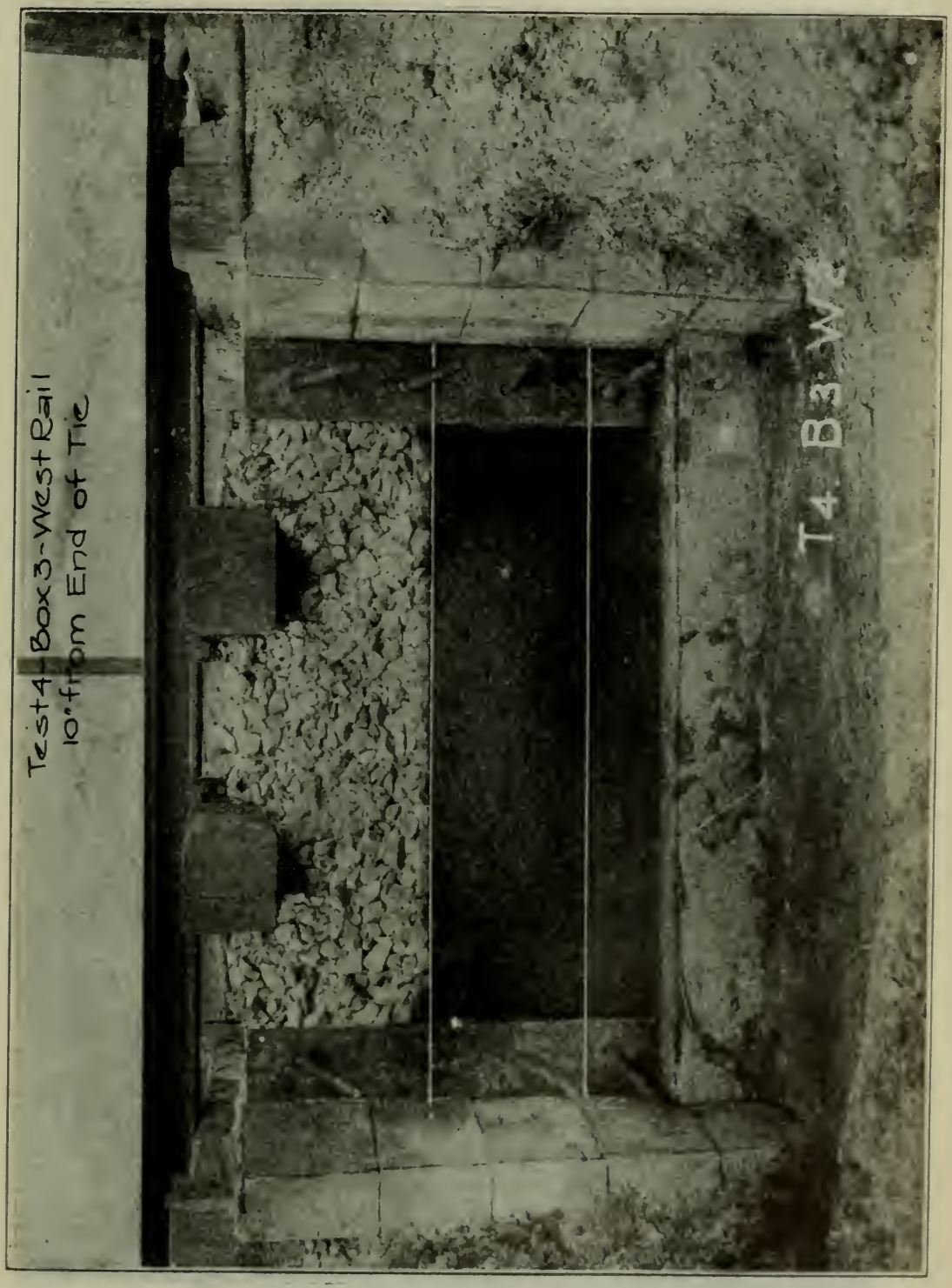

SECTIONS LOOKING THROUGH BOX
4th TEST
WEST RAIL
BOX No 2
STONE
SLAG
LOAM
ORIGINAL DIVIDING LINE TRAP ROCK BALLAST
ORIGINAL DIVIDING LINE SLAG BALLAST
SOUTH
2'0"
1'0"
2'1¾"
1¾
LEGEND
SETTLEMENT DIRECTLY UNDER RAIL
11" FROM END OF TIE
UNDER END OF TIE
SCALE 1" = 1'
DEC 6TH 1909

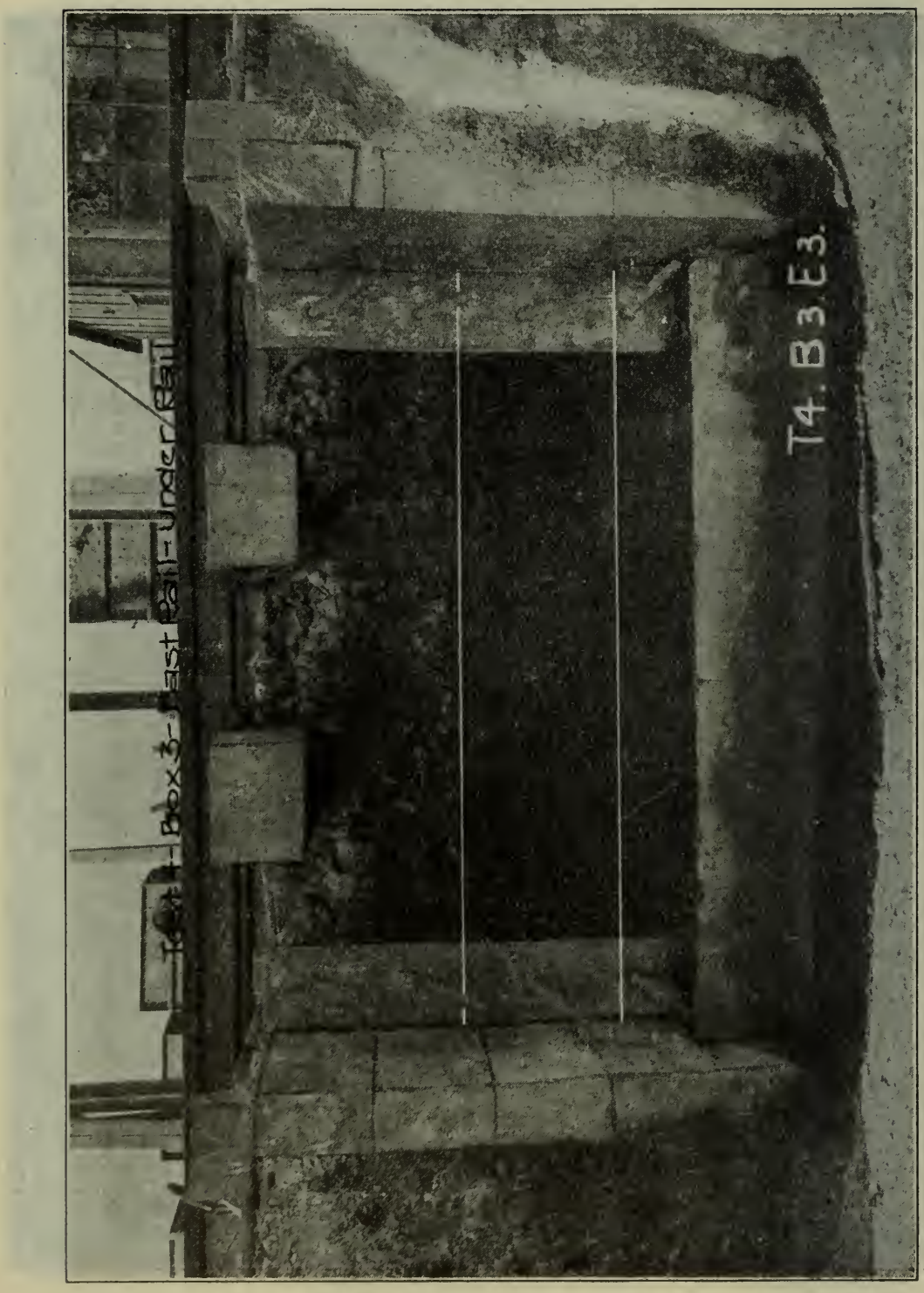

Box N° 2.
Section Through Box
Perpendicular to Rail
East Rail
West Rail
White Oak Squared Tie 7.9'8½
Stone
Original Dividing Line Trap Rock Ballast
Slag
Original Dividing Line Slag Ballast
Loam
Legend
Settlement Under North Tie
" " South "
" " Between Ties
Scale 1:1

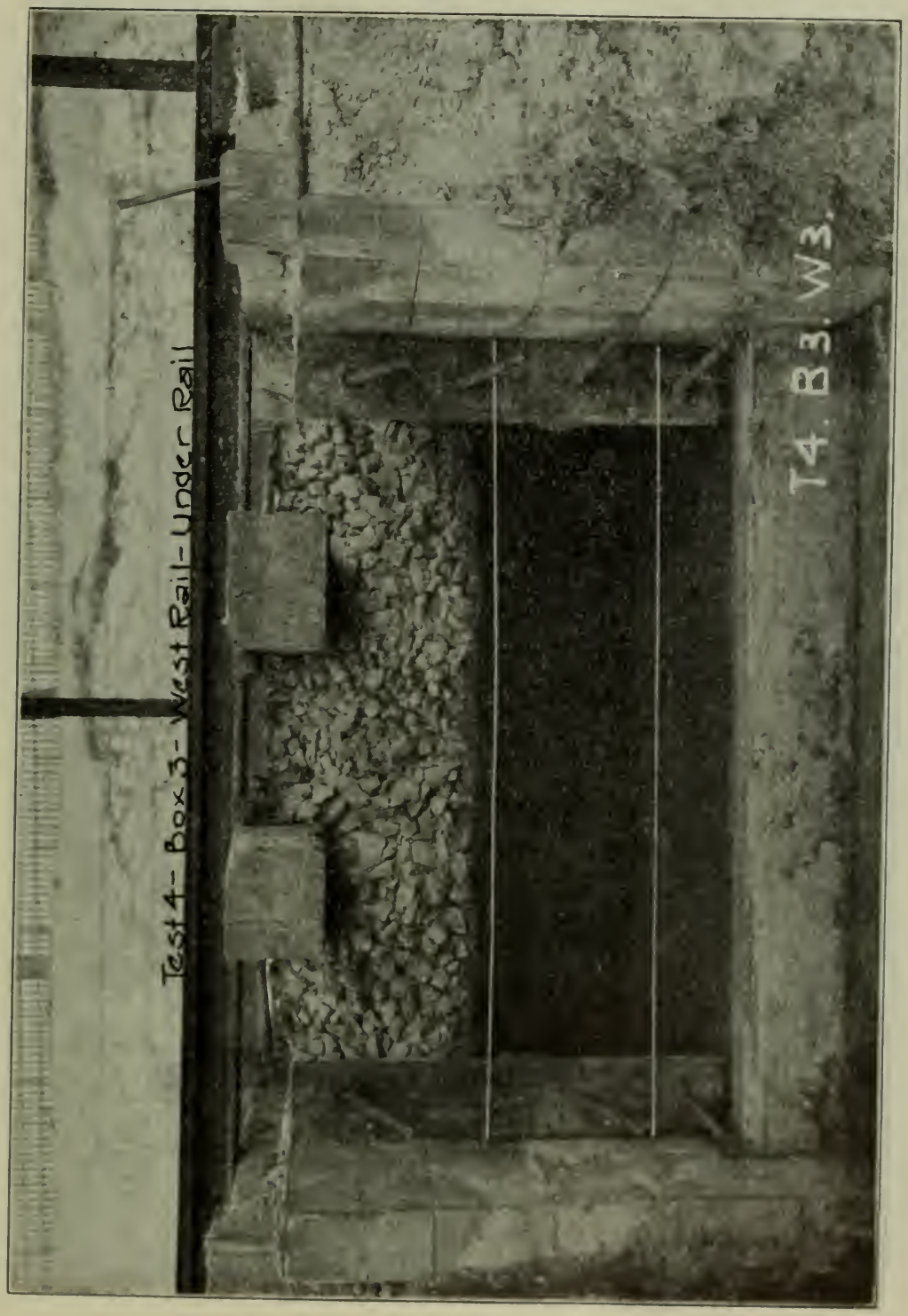

Test 4 Box 3 - East Rail - End of Tie
T4. B3. E1

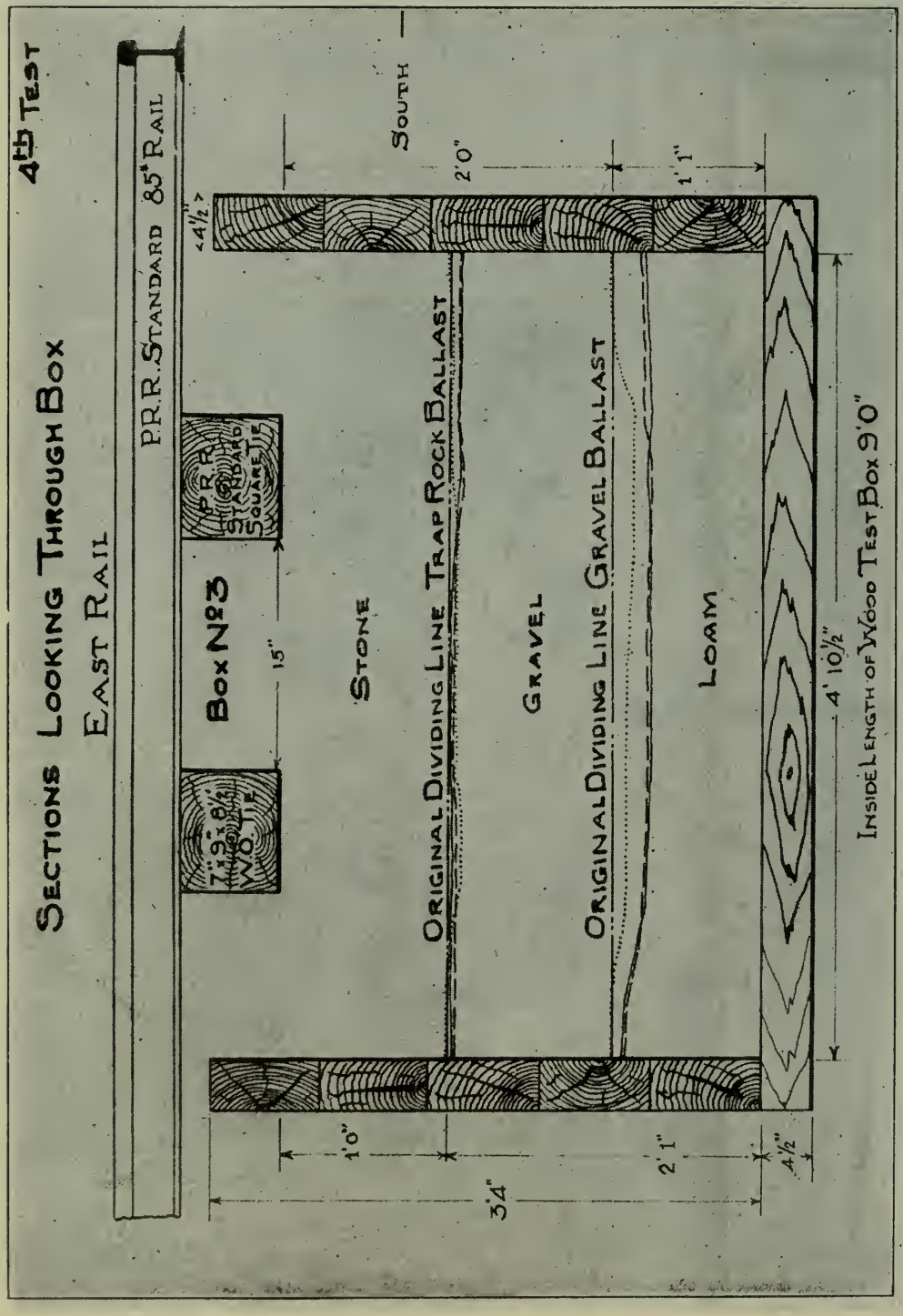

Test 4- Box 3- West Rail- End of Tie
T4 B3 W1

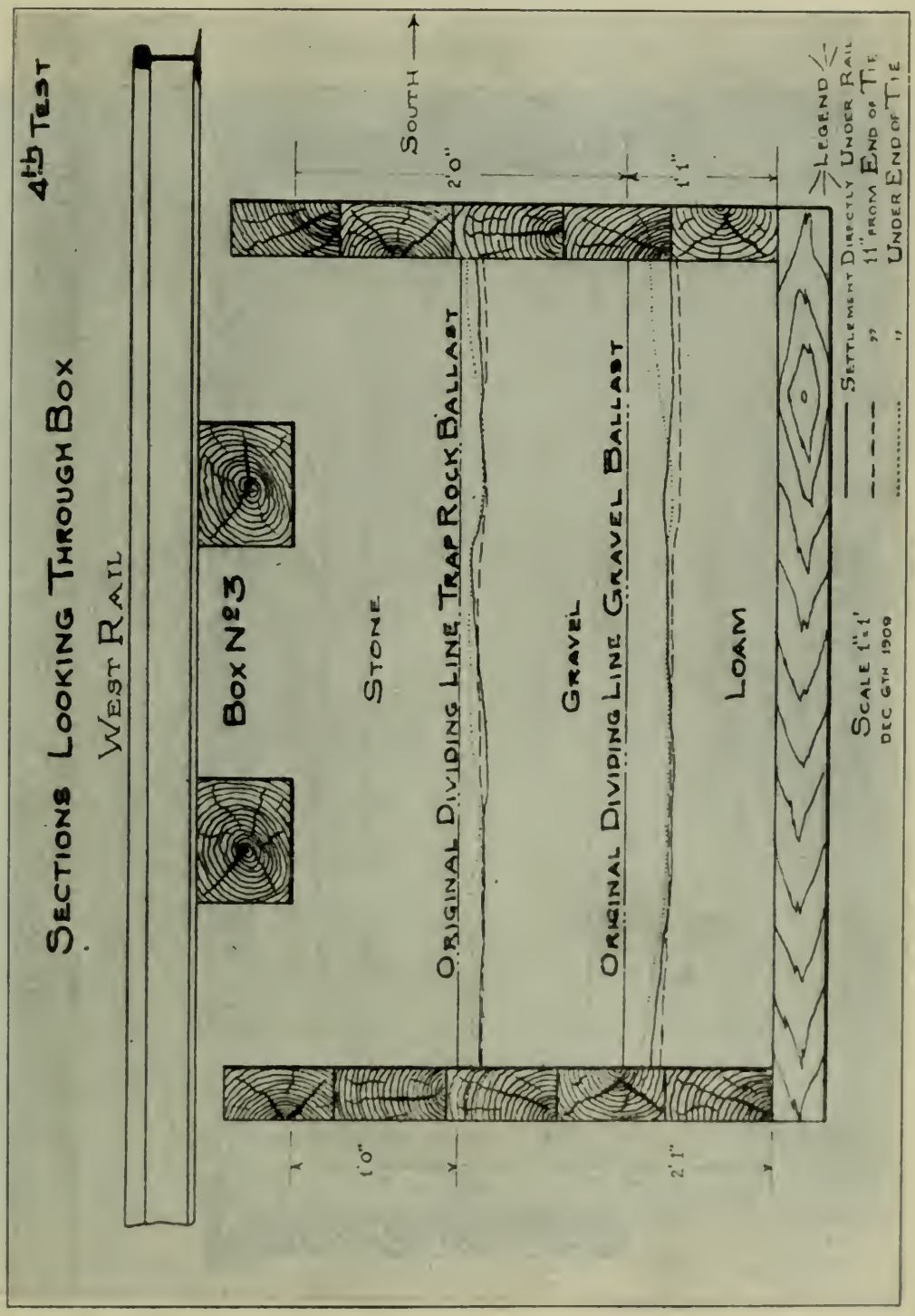

T4. B3. E2.

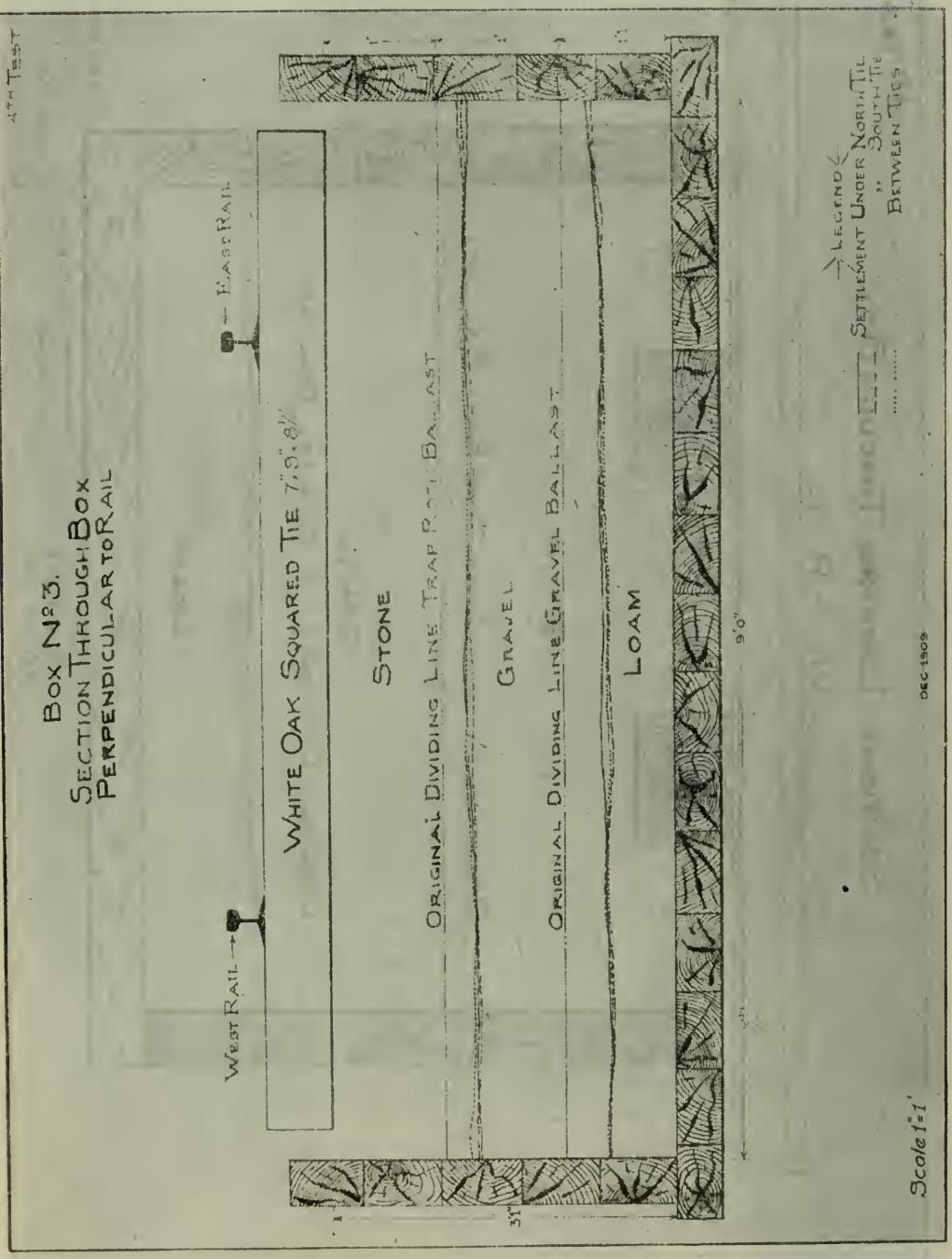

Test 4 - Box 3 - West Rail
10" from End of Tie
T 4 B 3 W

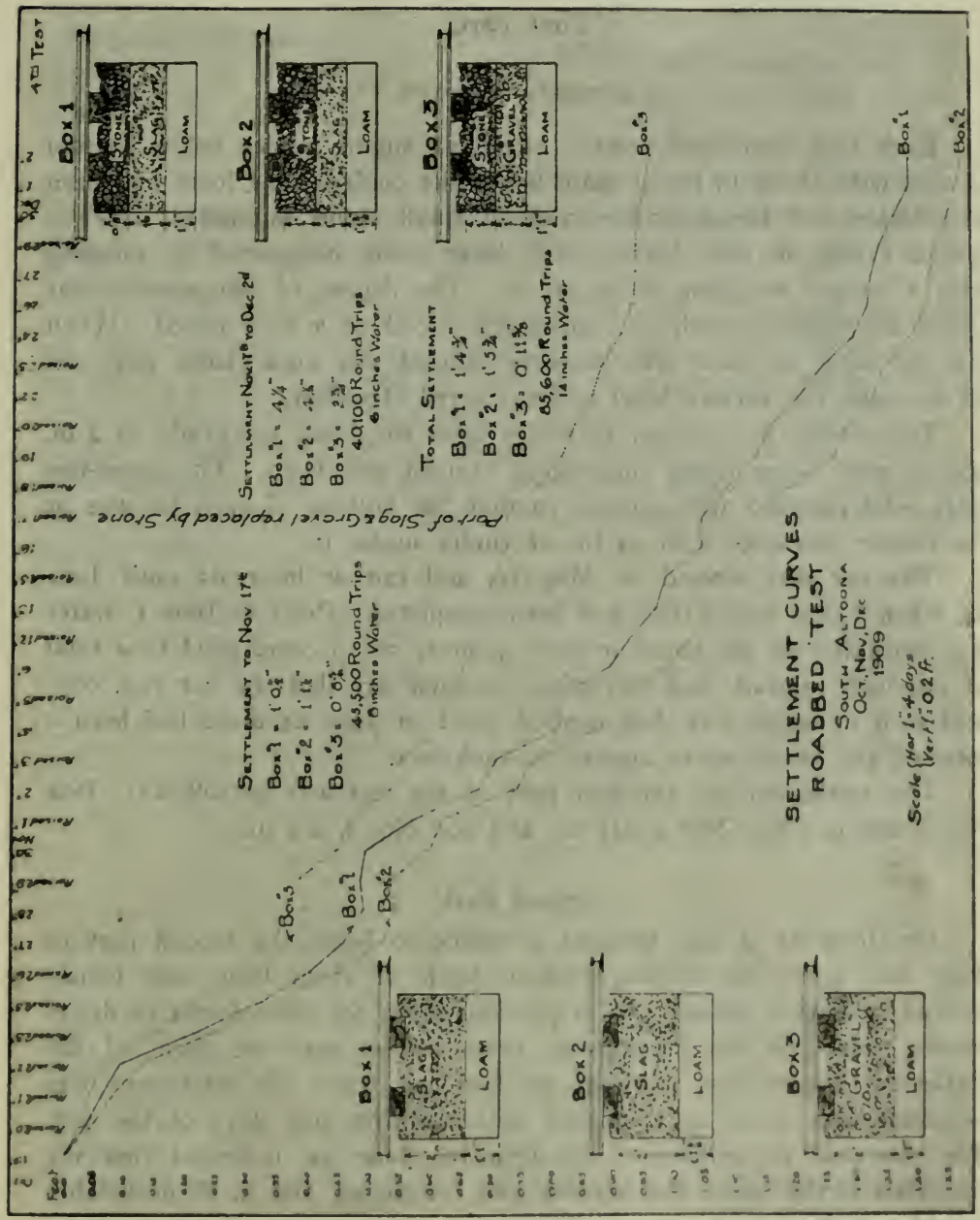

T4. B3. E3.


Test 4- Box 3- West Rail- Under Rail
T4. B3. W3.


4th Test
Sections Looking Through Box
East Rail
P.R.R. Standard 85# Rail
Box N°3
P.R.R. Standard Square Tie
7"x9"x8'-6" White Oak Tie
15"
Stone
Original Dividing Line Trap Rock Ballast
Gravel
Original Dividing Line Gravel Ballast
Loam
South
4½"
2'0"
1'1"
4'10½"
Inside Length of Wood Test Box 9'0"
1'0"
2'1"
34"
4½"


4th Test
Sections Looking Through Box
West Rail
Box No 3
South
2'0"
1'1"
Stone
Original Dividing Line Trap Rock Ballast
Gravel
Original Dividing Line Gravel Ballast
Loam
1'0"
2'1"
Legend
Settlement Directly Under Rail
" 11" from End of Tie
" Under End of Tie
Scale 1"=1'
Dec 6th 1909


47th Test
Box No 3.
Section Through Box
Perpendicular to Rail
East Rail
West Rail
White Oak Squared Tie 7'-3"-8"
Stone
Original Dividing Line Trap Rock Ballast
Gravel
Original Dividing Line Gravel Ballast
Loam
9'0"
31"
Legend
Settlement Under North Tie
" South Tie
Between Ties
Dec 1909
Scale 1"=1'


SETTLEMENT CURVES
ROADBED TEST
SOUTH ALTOONA
OCT. NOV. DEC
1909
Box 1
Box 2
Box 3
STONE
SLAG
GRAVEL
LOAM
Part of Slag & Gravel replaced by Stone
SETTLEMENT TO NOV 17th
Box 1 - 1 0¾"
Box 2 - 1 1¾"
Box 3 - 0 6½"
43,500 Round Trips
8 inches Water
SETTLEMENT NOV 17th TO DEC 2nd
Box 1 - ¾"
Box 2 - ¾"
Box 3 - ¾"
40,100 Round Trips
8 inches Water
TOTAL SETTLEMENT
Box 1 - 1 4½"
Box 2 - 1 5¾"
Box 3 - 0 11½"
85,600 Round Trips
16 inches Water

TEST NO. 5.

May 19 to August 2, 1910.

First Part.

MATERIAL IN BOXES.

Each box contained exactly 24 in. of engine cinder below bottom of ties, with about 13 in. of loam below the cinder. The loam had been well forked, all lumps broken and all small stone eliminated. It was spread evenly in 4-in. layers, each layer being compacted by tamping with a tamper weighing about 20 lbs. The degree of compactness was tested by prodding with the unsharpened end of a lead pencil. When the last layer of loam was properly tamped, the high places were cut off to make the surface level to the desired elevation.

The cinder was spread carefully upon the loam sub-grade in 4-in. layers, each layer being thoroughly tamped as above. The cross-ties were well rammed with cinder, so that the bottom of each tie was at the proper elevation with 24 in. of cinder under it.

The car was started on May 19, and ran at intervals until June 24, when 19,210 round trips had been completed. Prior to June 1, water was sprinkled on the boxes in such quantity as to correspond to a total of one-inch rainfall, and thereafter on each day that the car ran, one-half inch of water was thus applied, until on June 24 there had been a total of 4½ in. of water applied to each box.

The settlement for the first part of the test was as follows: Box No. 1, 2¾ in.; box No. 2, 2⅞ in., and box No. 3, 2½ in.

Second Part.

On June 24, it was thought advisable to begin the second part of Test No. 5, by substituting certain depth of clean trap rock ballast instead of engine cinder. As in previous tests, the chief factor in determining the time for introducing stone ballast was the form of the settlement curves just previous to June 24, when the settlement was becoming less daily, as compared with the first few days of the test. The decrease in settlement just prior to June 24, indicated that the materials in the boxes had become well compacted, and in all probability would not show much more settlement.

The statement of conditions below shows the changes in the materials in the boxes when the car was again started on June 24, continuing until August 2, making 93,094 additional round trips, or a total of 112,304 round trips.

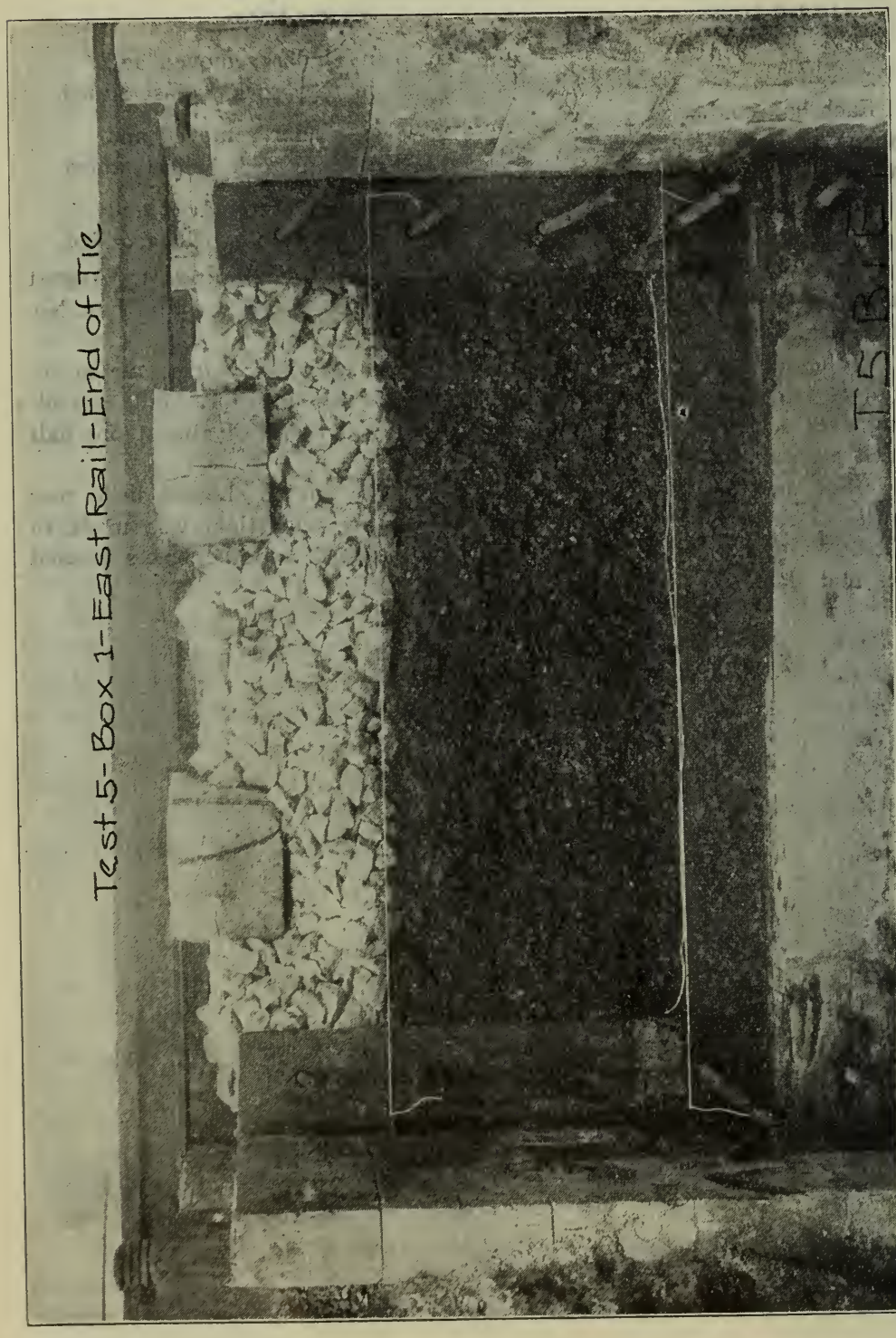
Statement of Conditions.

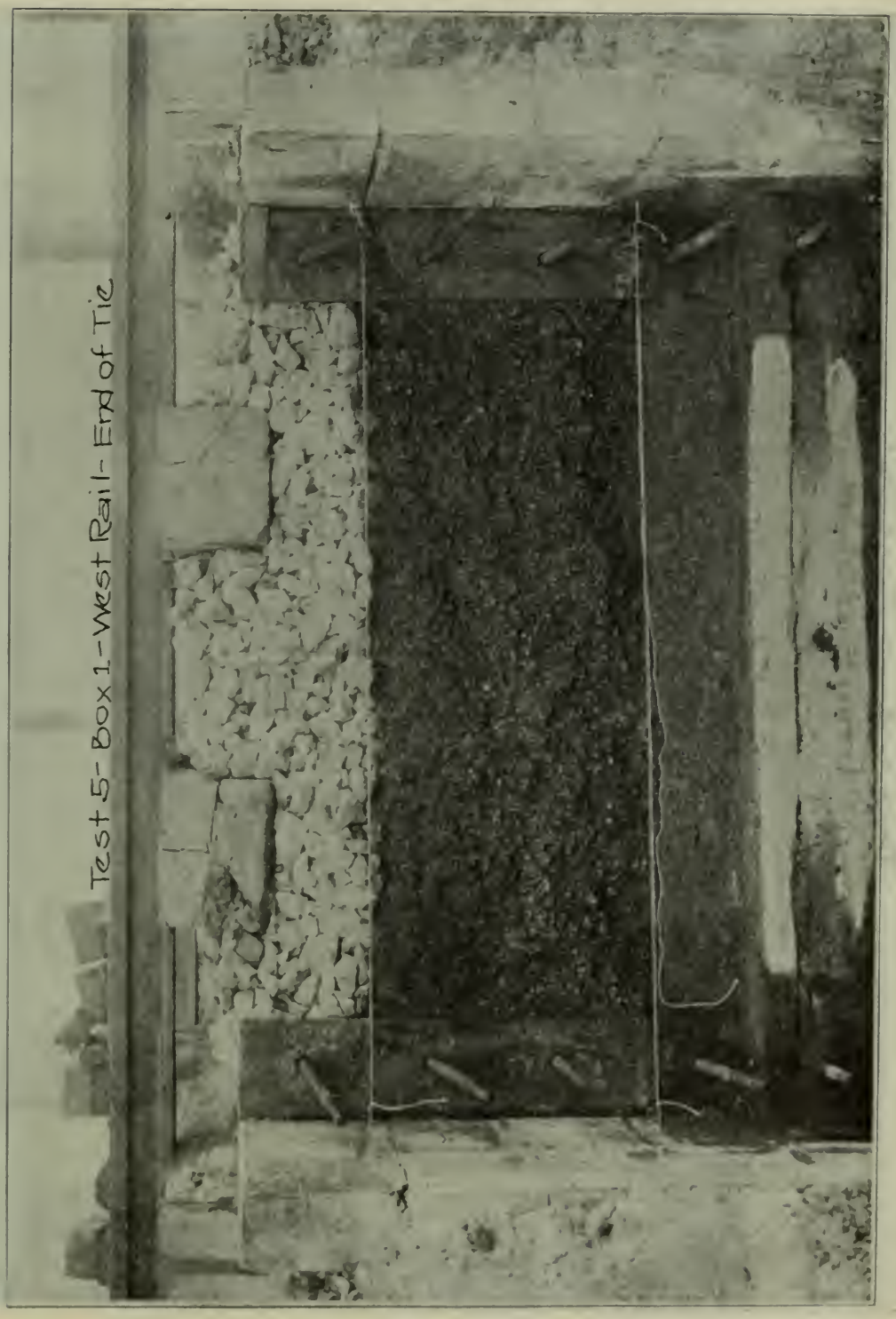
First part, 19,210 trips.		Second part, 93,094 trips.
Each box contained about 13 in. of loam and 24 in. of cinder.	Box No. 1	6 in. cinder removed and 6 in. trap rock ballast added.
	Box No. 2	8 in. cinder removed and 8 in. trap rock ballast added.
	Box No. 3	10 in. cinder removed and 10 in. trap rock ballast added.

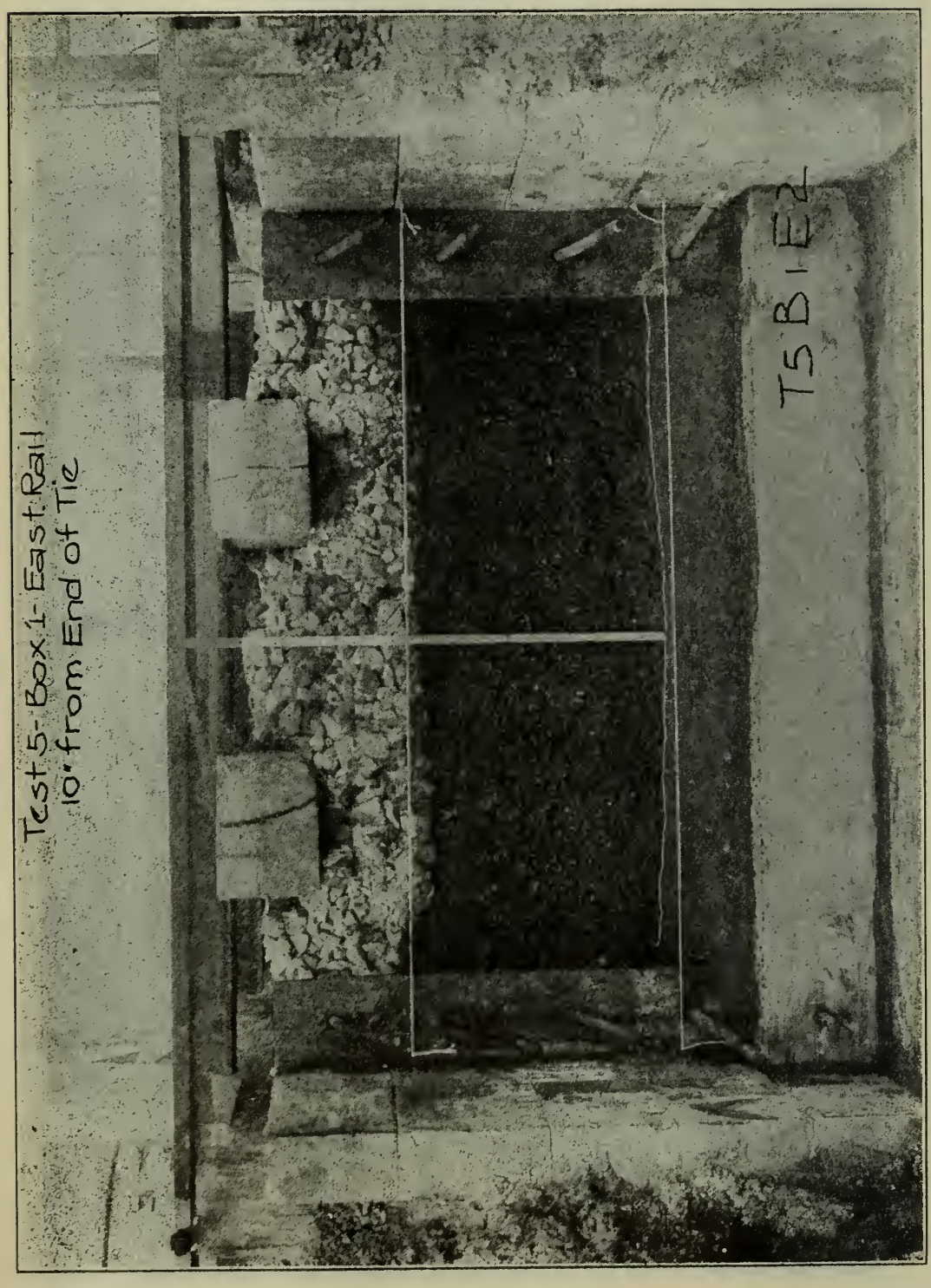
The settlement for the second part of the test, June 24 to August 2, was as follows: Box No. 1, 5¼ in.; box No. 2, 5$\frac{7}{16}$ in., and box No. 3, 4½ in.

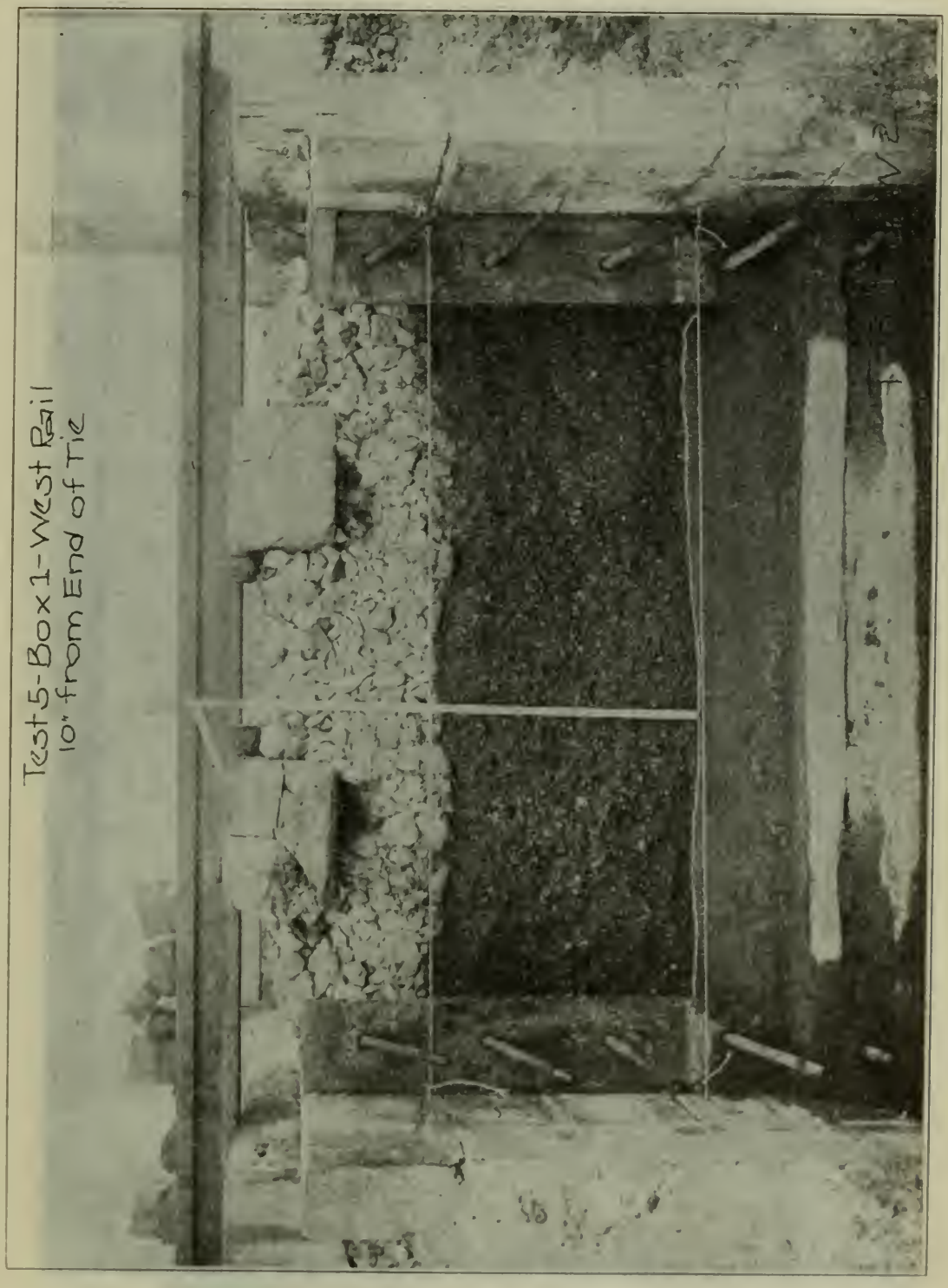
The total amount of water sprinkled on each box during the entire run of 112,304 round trips was equivalent to 18½ in. of rainfall, extending over a period of 46 running days, or an average of almost one-half inch per running day, after June 1.

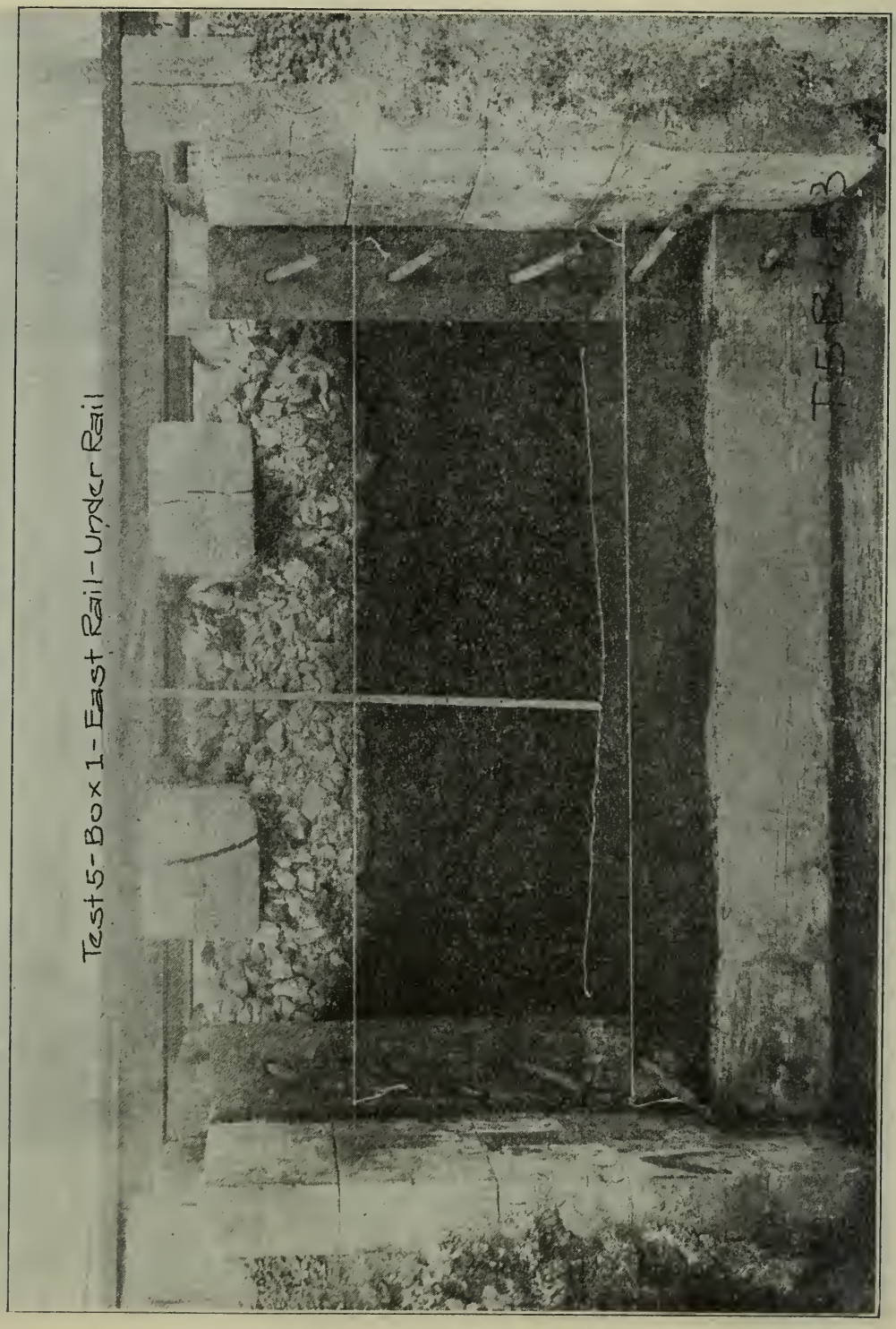
For several days prior to August 2, the curves showed little material settlement, and having made even more trips than was made in Test No. 3, namely, 85,600, the car was stopped and the boxes opened on that date.

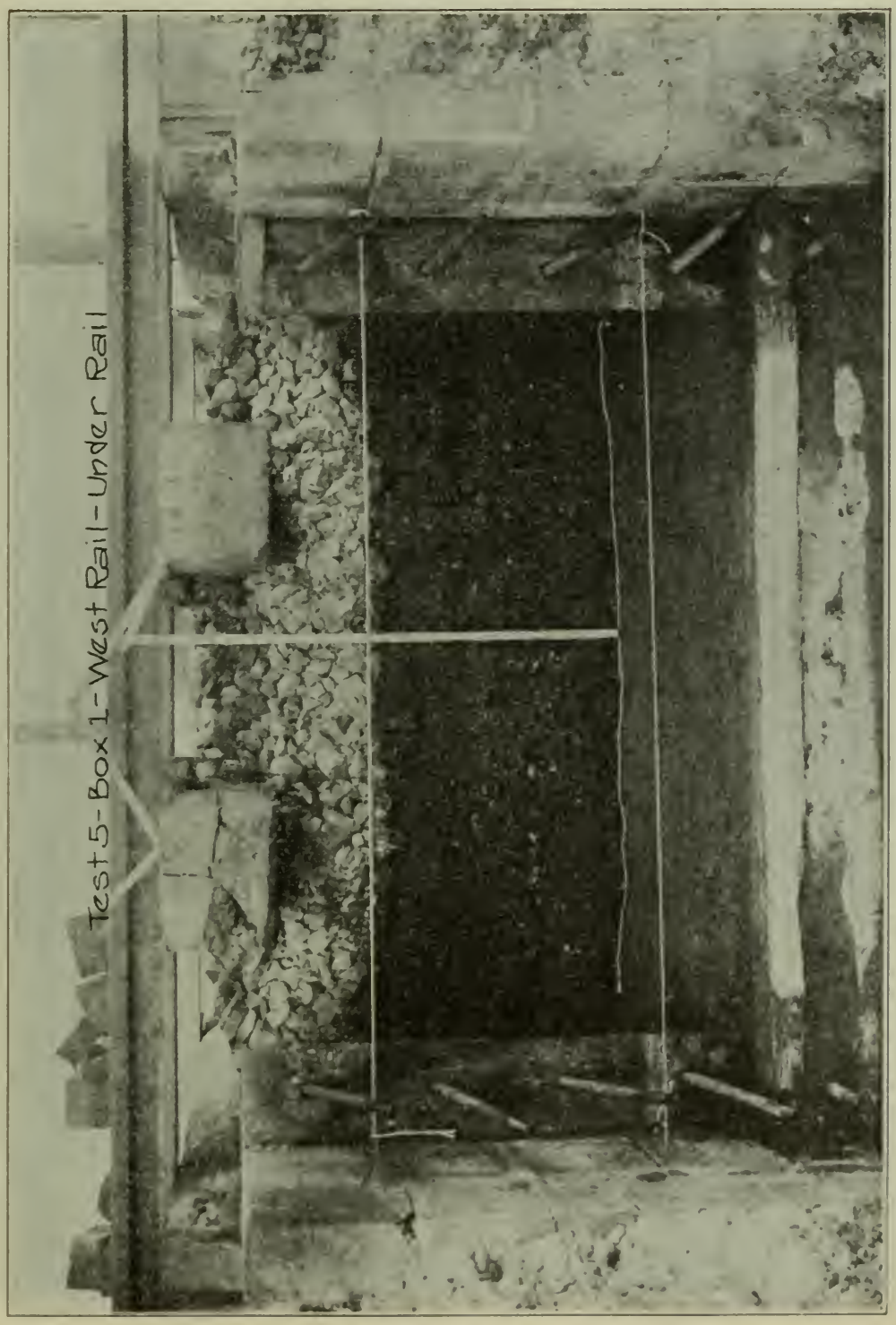

Test 5- Box 1- East Rail- End of Tie

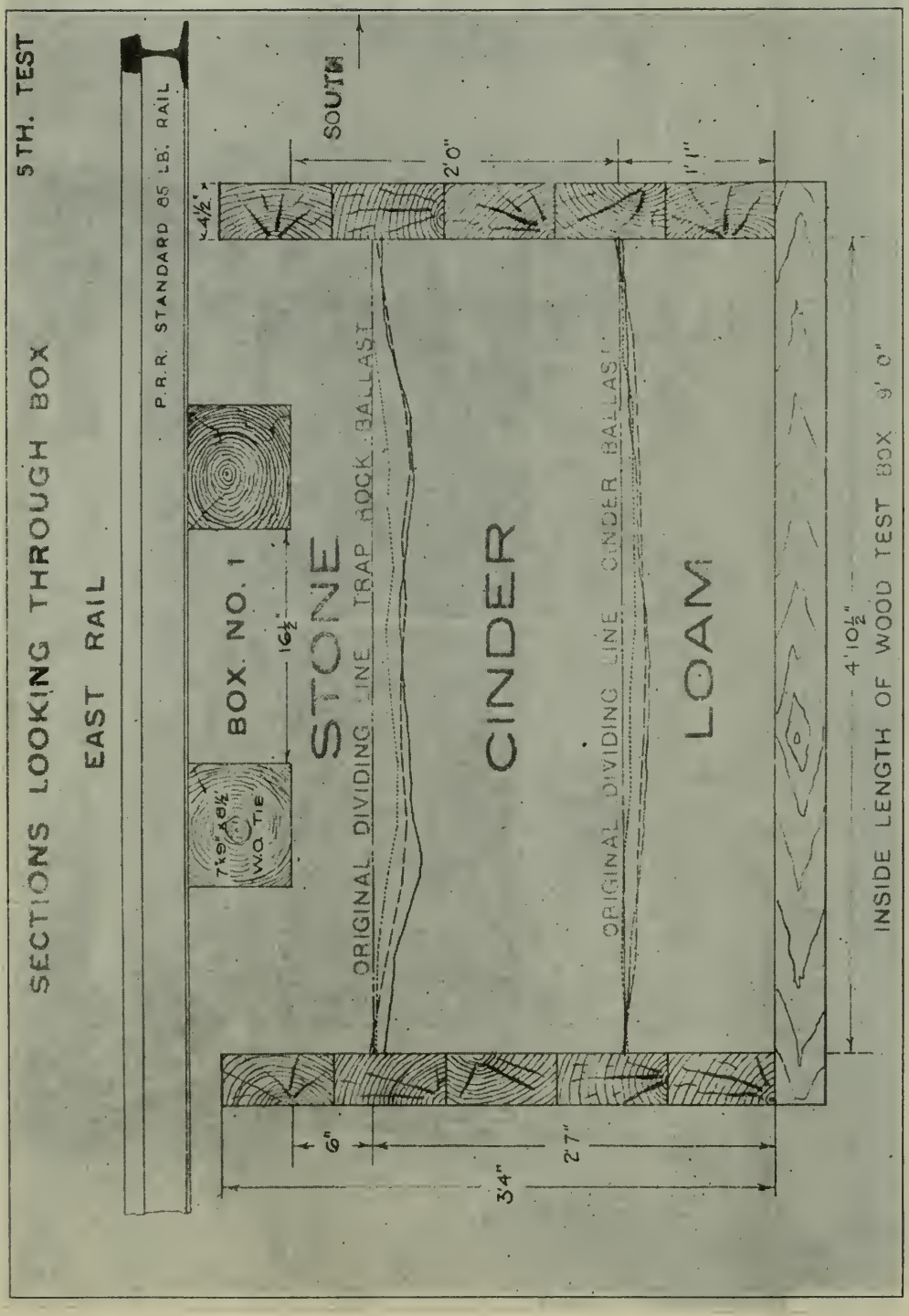

Test 5- Box 1.- West Rail- End of Tie

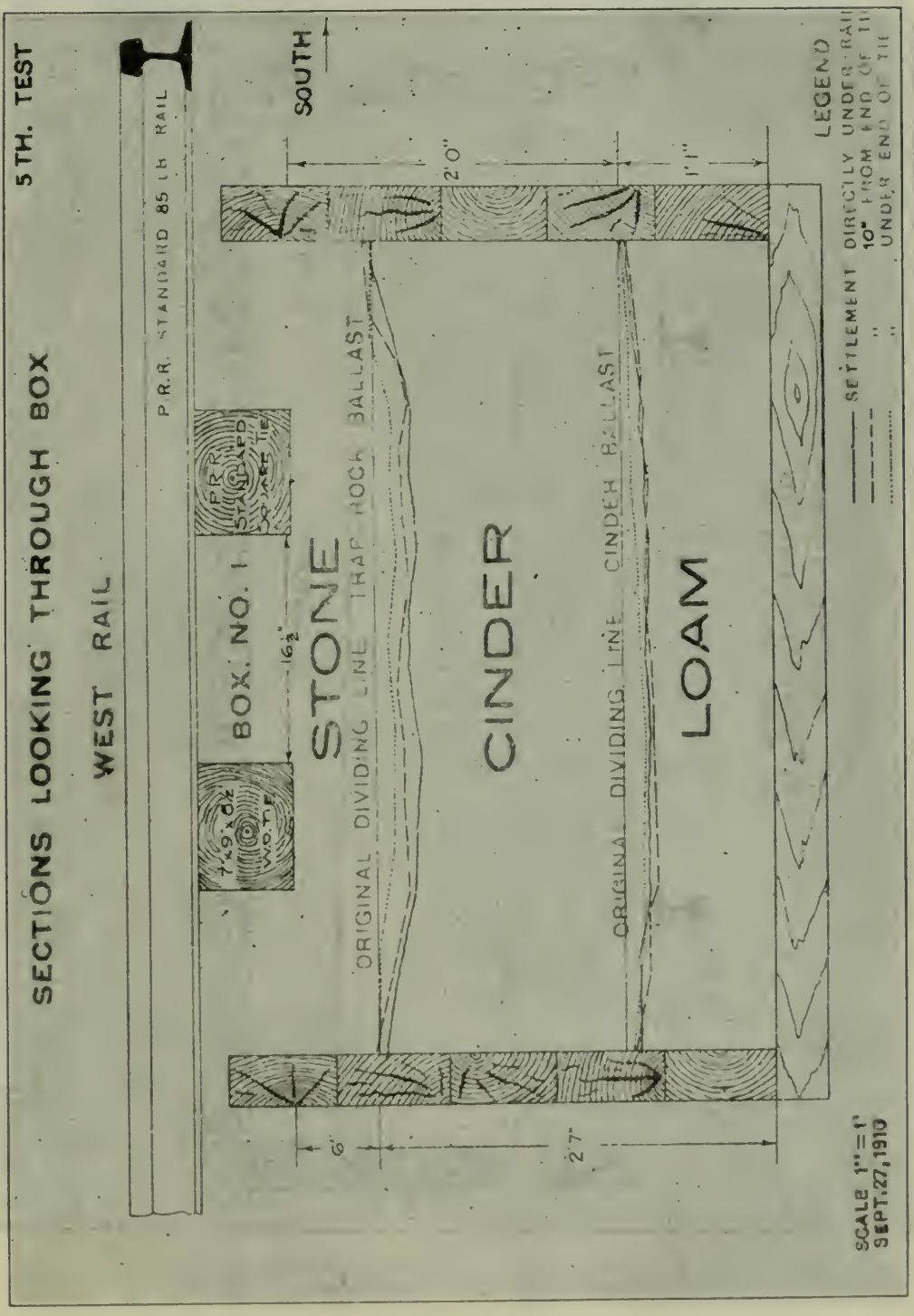

Test 5- Box 1- East Rail
10' from End of Tie
T5 B1 E2

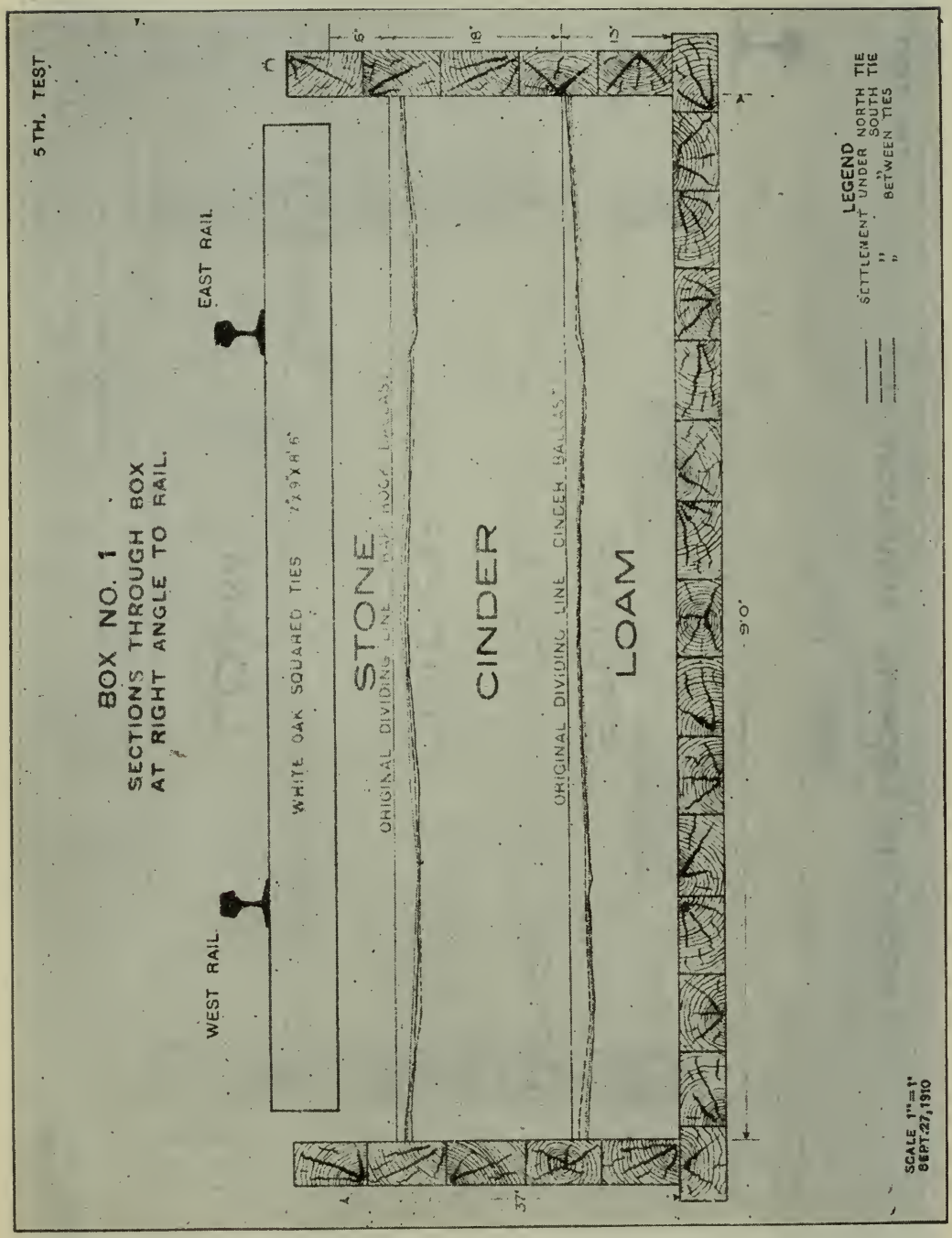

Test 5-Box 1-West Rail
10" from End of Tie

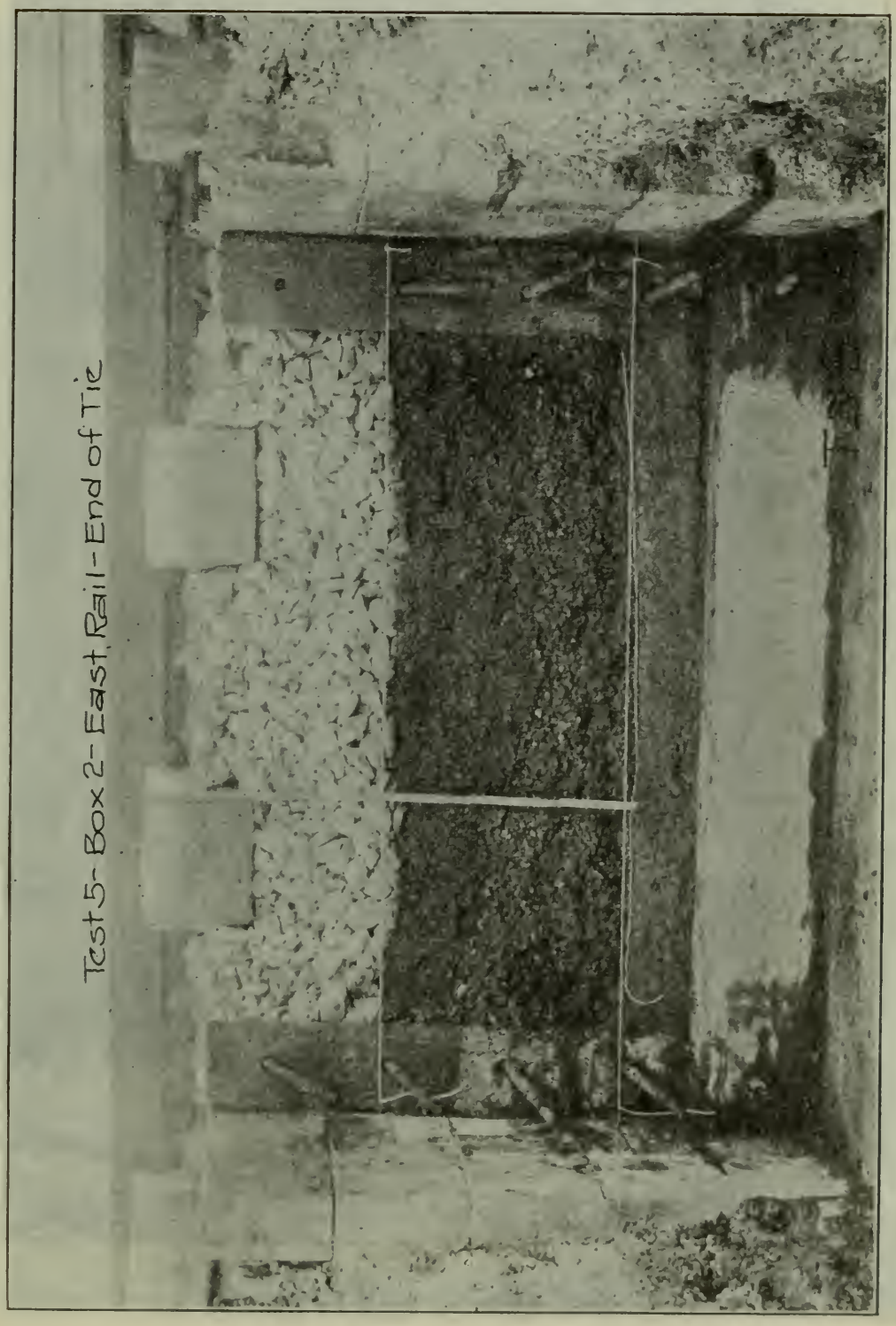

Test 5 - Box 1 - East Rail - Under Rail

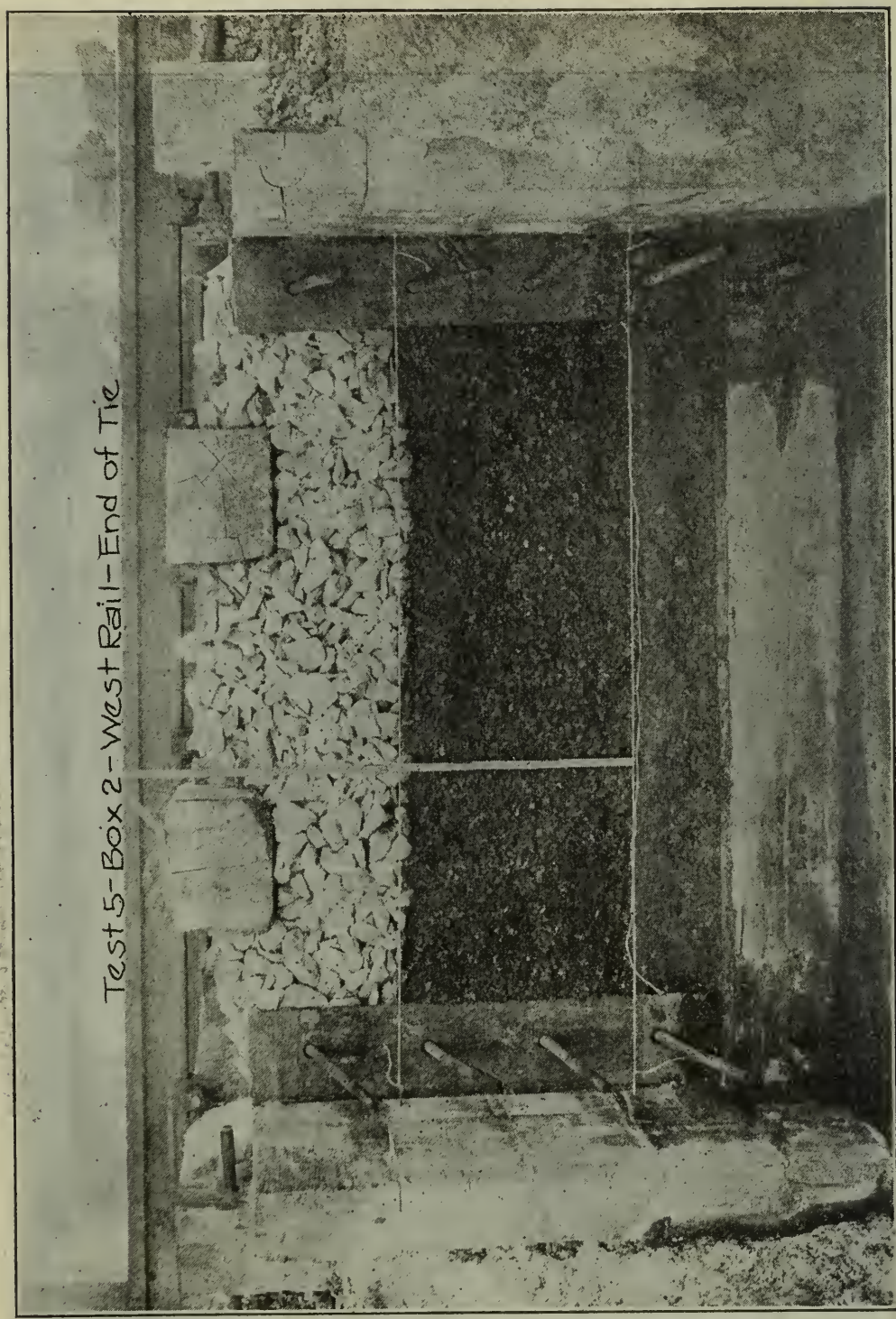

Test 5- Box 1- West Rail- Under Rail

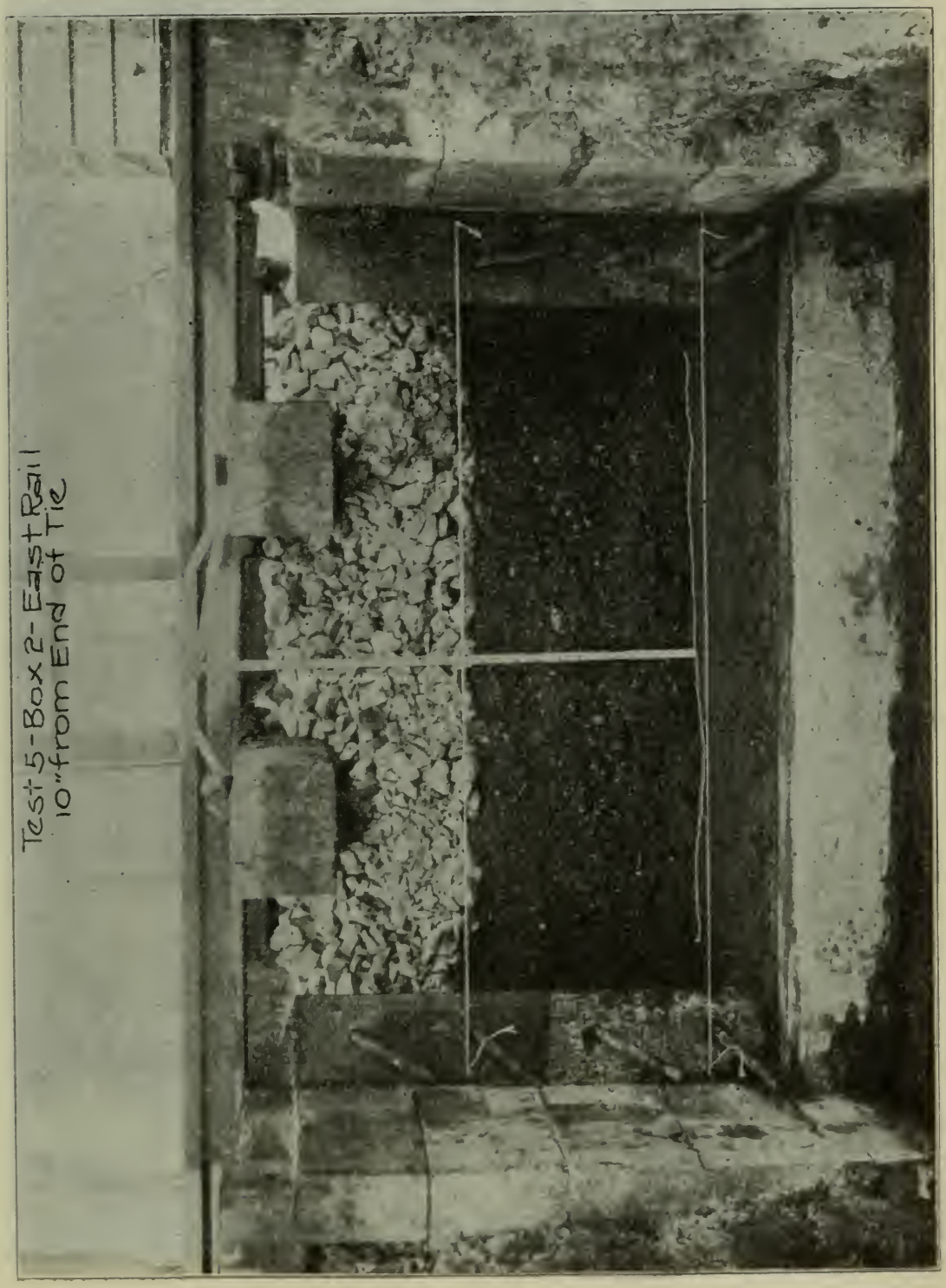

SECTIONS LOOKING THROUGH BOX
5TH. TEST
EAST RAIL
P.R.R. STANDARD 85 LB. RAIL
SOUTH
2'0"
1'1"
4½"
BOX. NO. 1
16½"
7"x8" Adz'd W.O. Tie
STONE
ORIGINAL DIVIDING LINE TRAP ROCK BALLAST
CINDER
ORIGINAL DIVIDING LINE CINDER BALLAST
LOAM
4'10½"
INSIDE LENGTH OF WOOD TEST BOX 9' 0"
6"
27"
34"

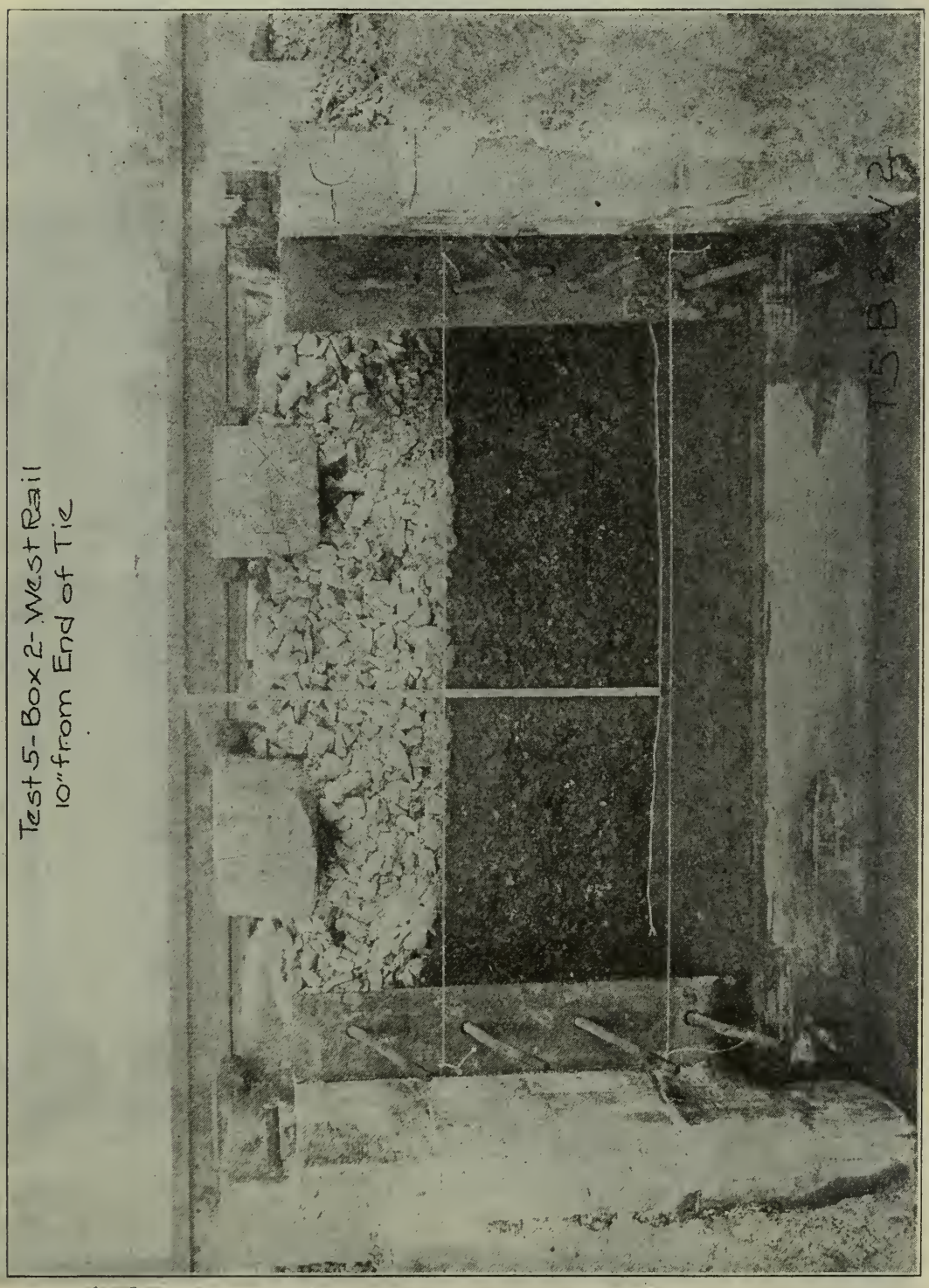

SECTIONS LOOKING THROUGH BOX
5TH. TEST
WEST RAIL
P.R.R. STANDARD 85 LH RAIL
SOUTH
BOX. NO. 1
STONE
CINDER
LOAM
ORIGINAL DIVIDING LINE TRAP ROCK BALLAST
ORIGINAL DIVIDING LINE CINDER BALLAST
2'0"
1'1"
6"
2'7"
LEGEND
SETTLEMENT DIRECTLY UNDER RAIL
10" FROM END OF TIE
UNDER END OF TIE
SCALE 1"=1'
SEPT. 27, 1910

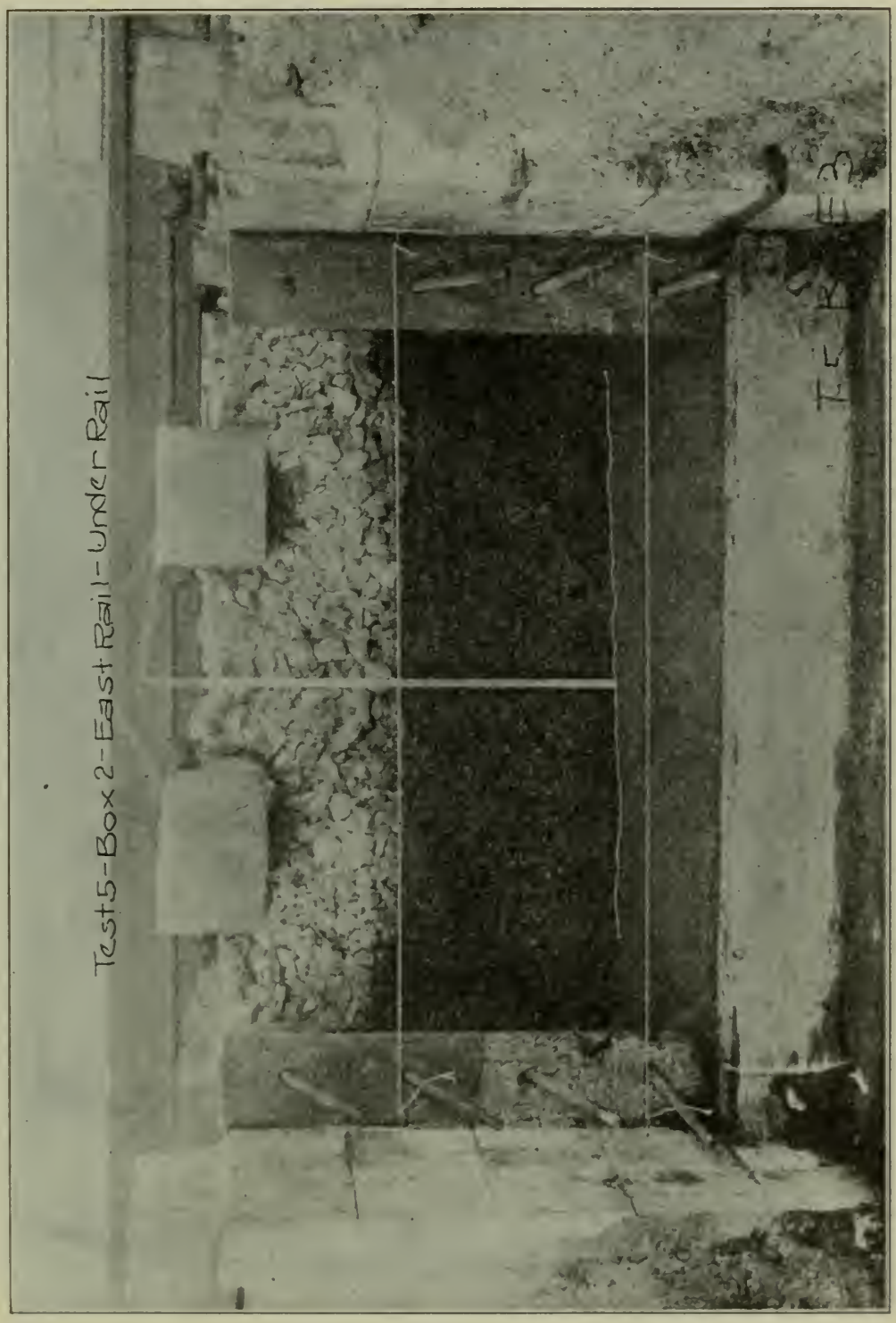

5TH. TEST
BOX NO. 1
SECTIONS THROUGH BOX
AT RIGHT ANGLE TO RAIL.
EAST RAIL
WEST RAIL
WHITE OAK SQUARED TIES
STONE
CINDER
LOAM
ORIGINAL DIVIDING LINE
ORIGINAL DIVIDING LINE CINDER BALLAST
6'
18'
15'
9'0"
37"
LEGEND
SETTLEMENT UNDER NORTH TIE
" " SOUTH TIE
" BETWEEN TIES
SCALE 1"=1'
SEPT. 27, 1910

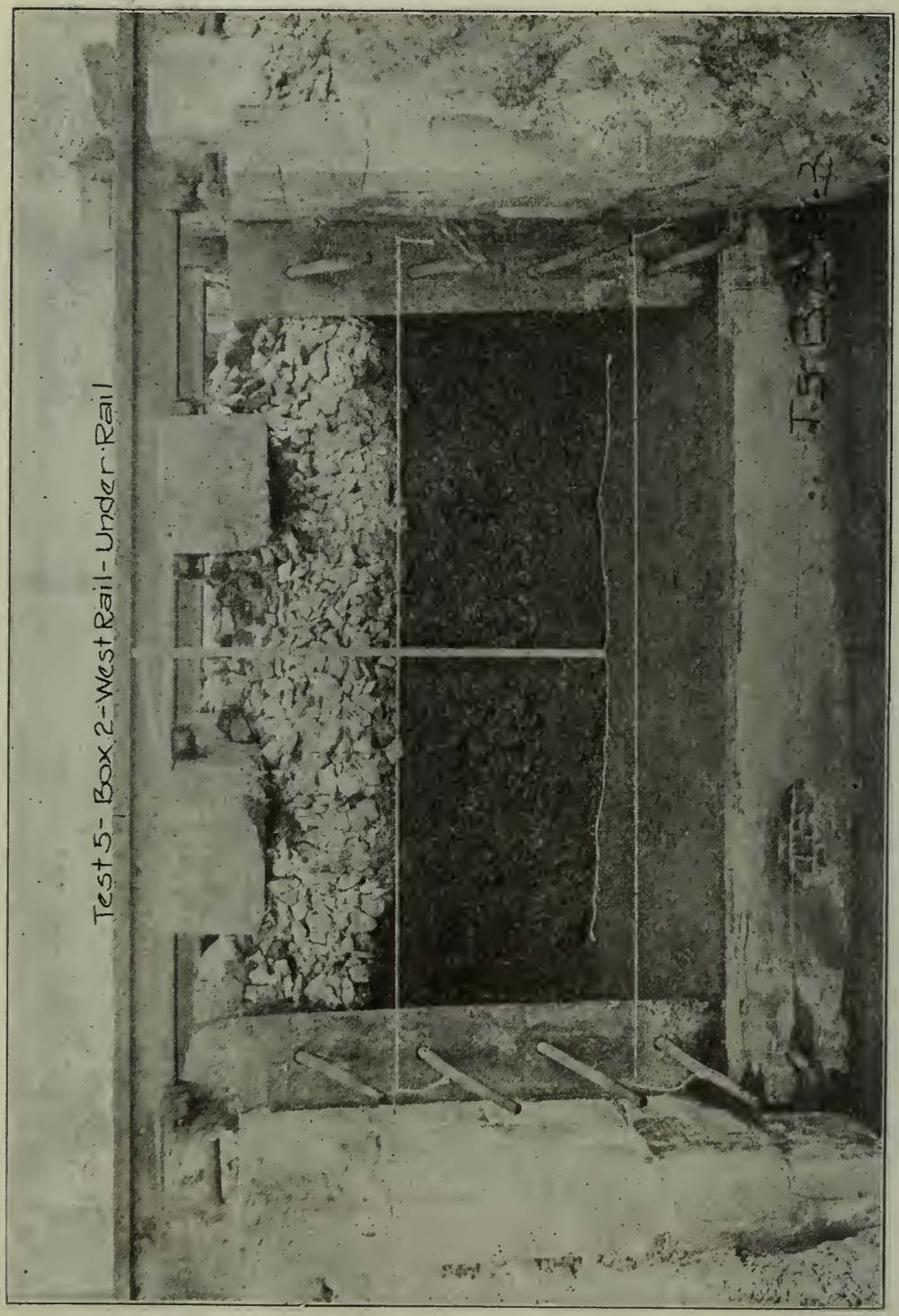

Test 5- Box 2- East Rail- End of Tie

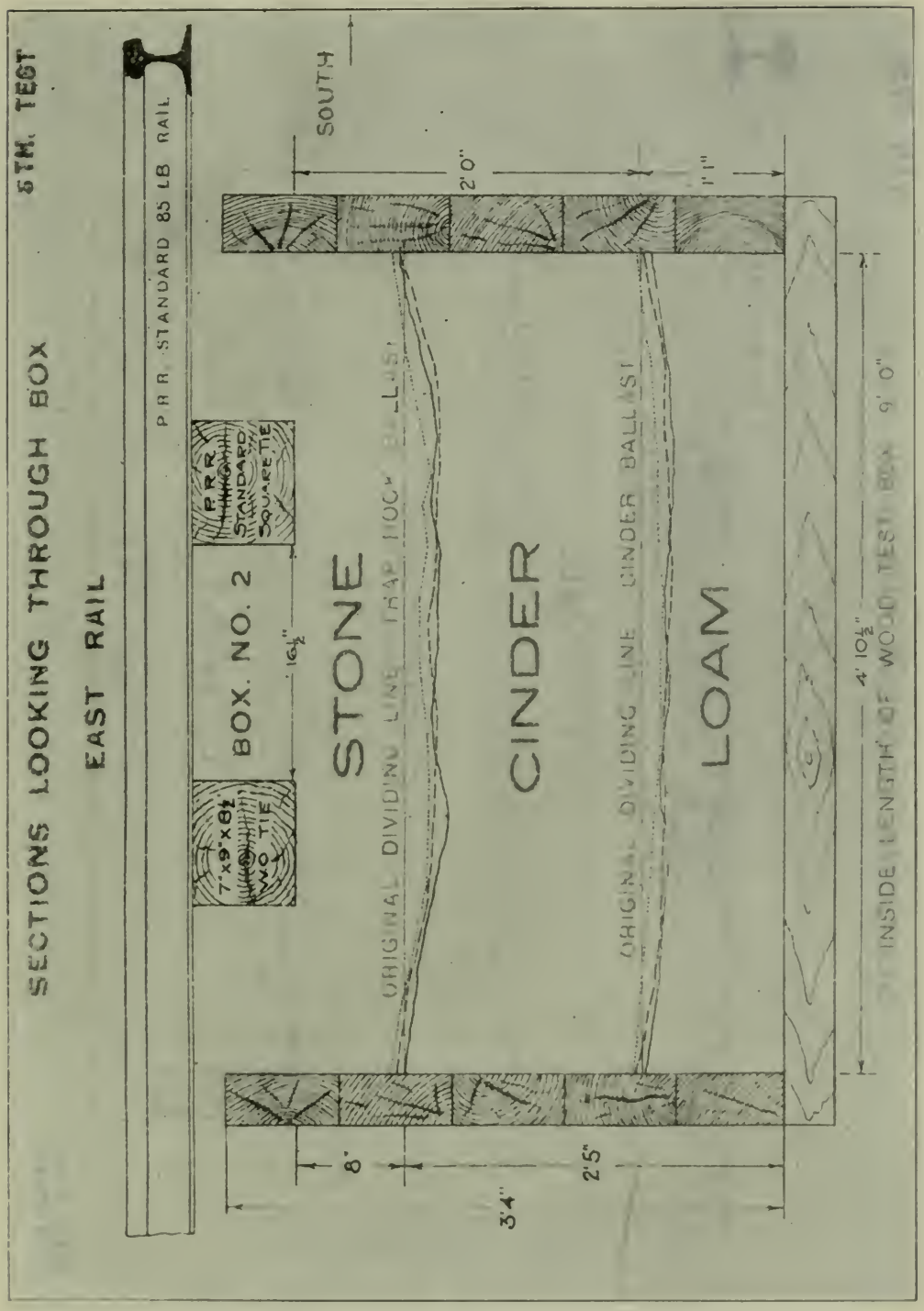

Test 5-Box 2-West Rail-End of Tie

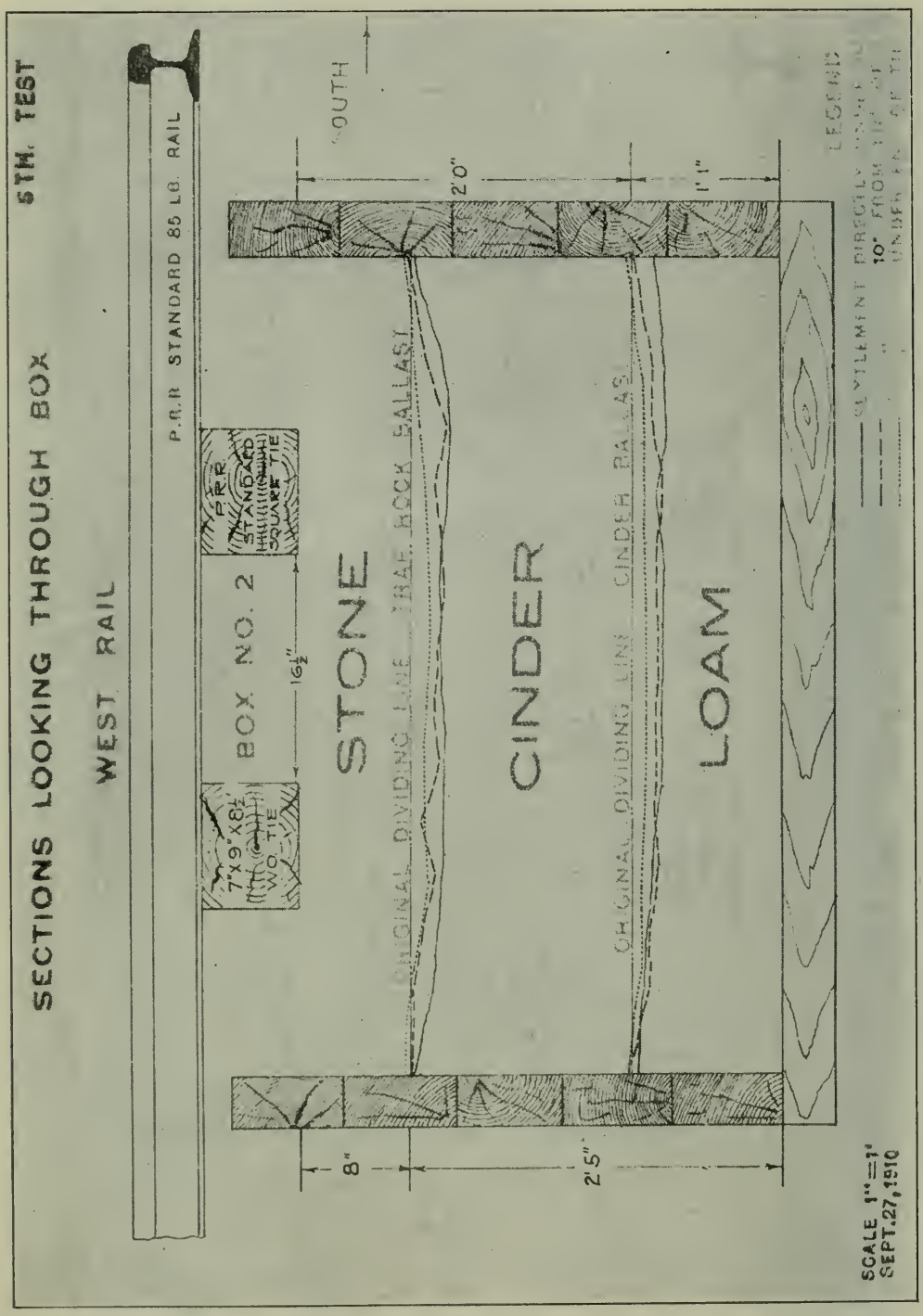

Test 5-Box 2-East Rail
10" from End of Tie

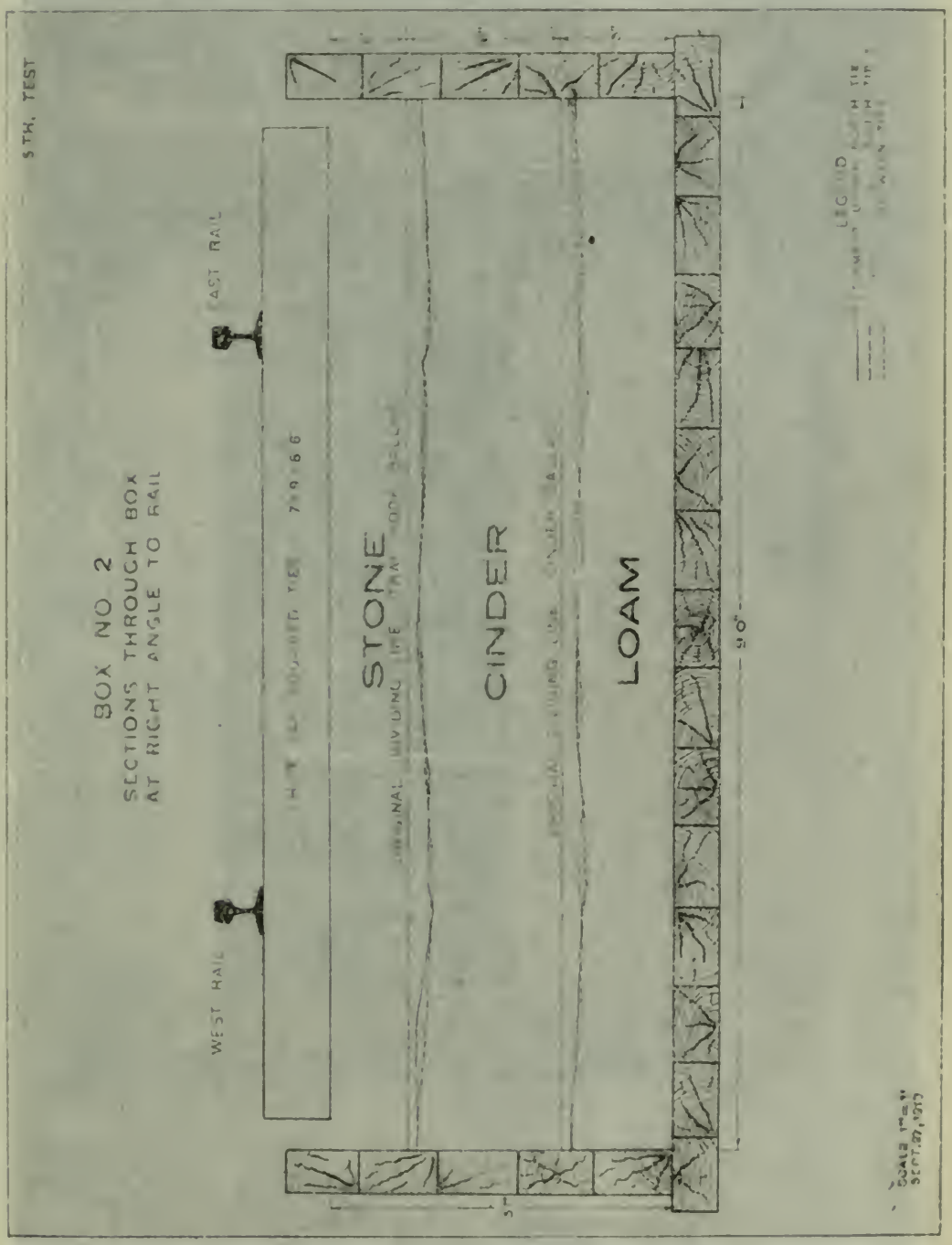

Test 5- Box 2- West Rail
10" from End of Tie

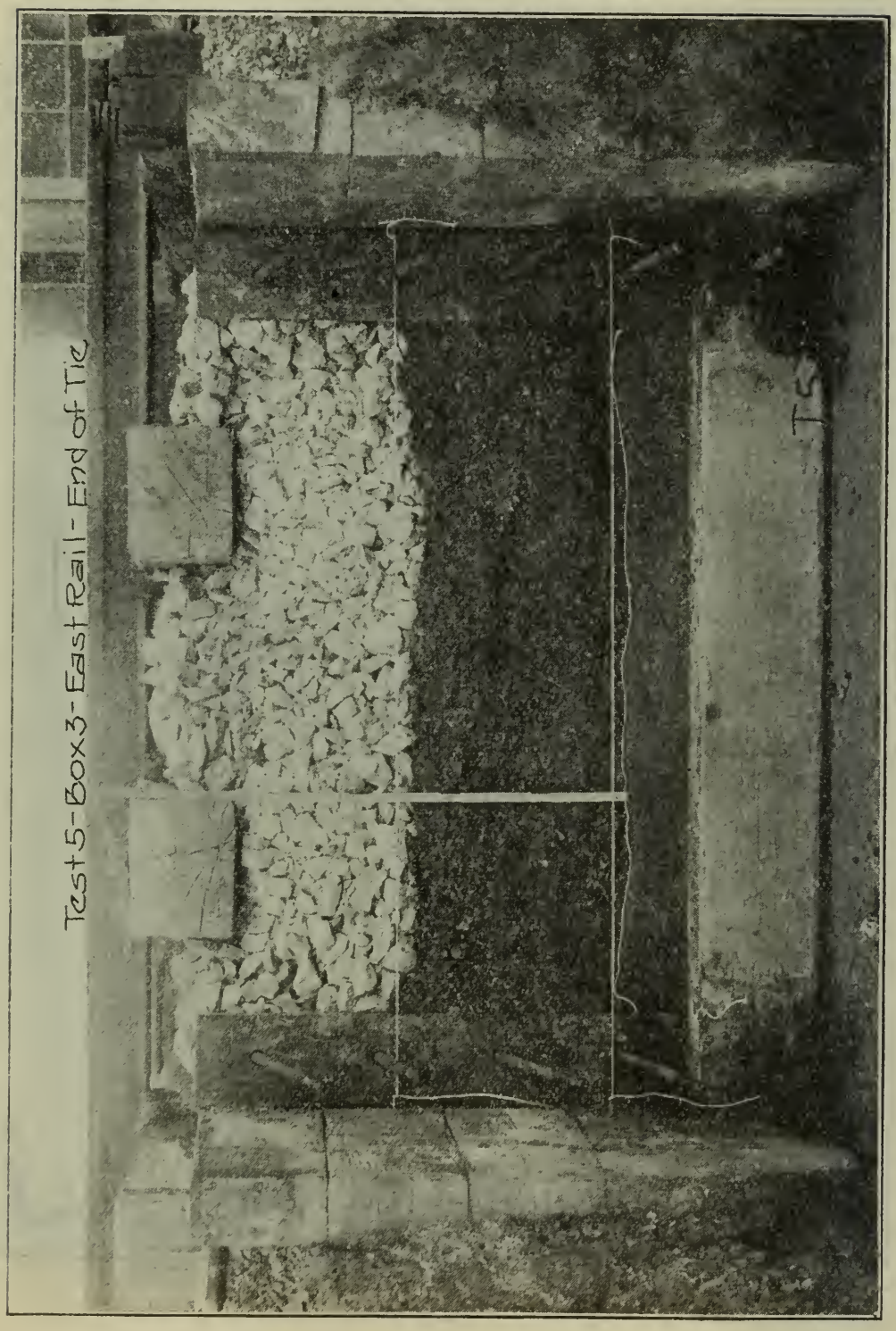

Test 5 - Box 2 - East Rail - Under Rail

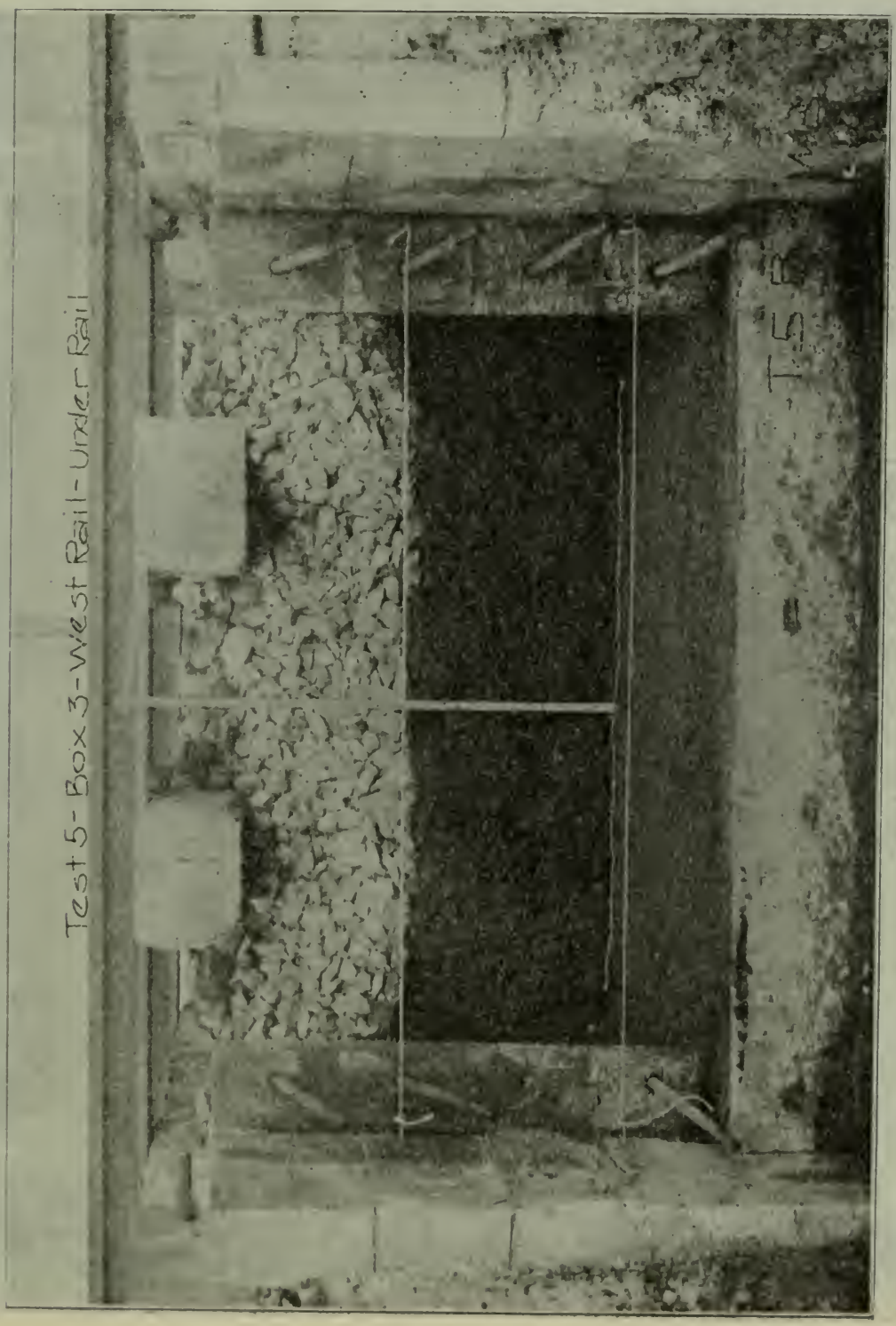

Test 5- Box 2- West Rail- Under Rail

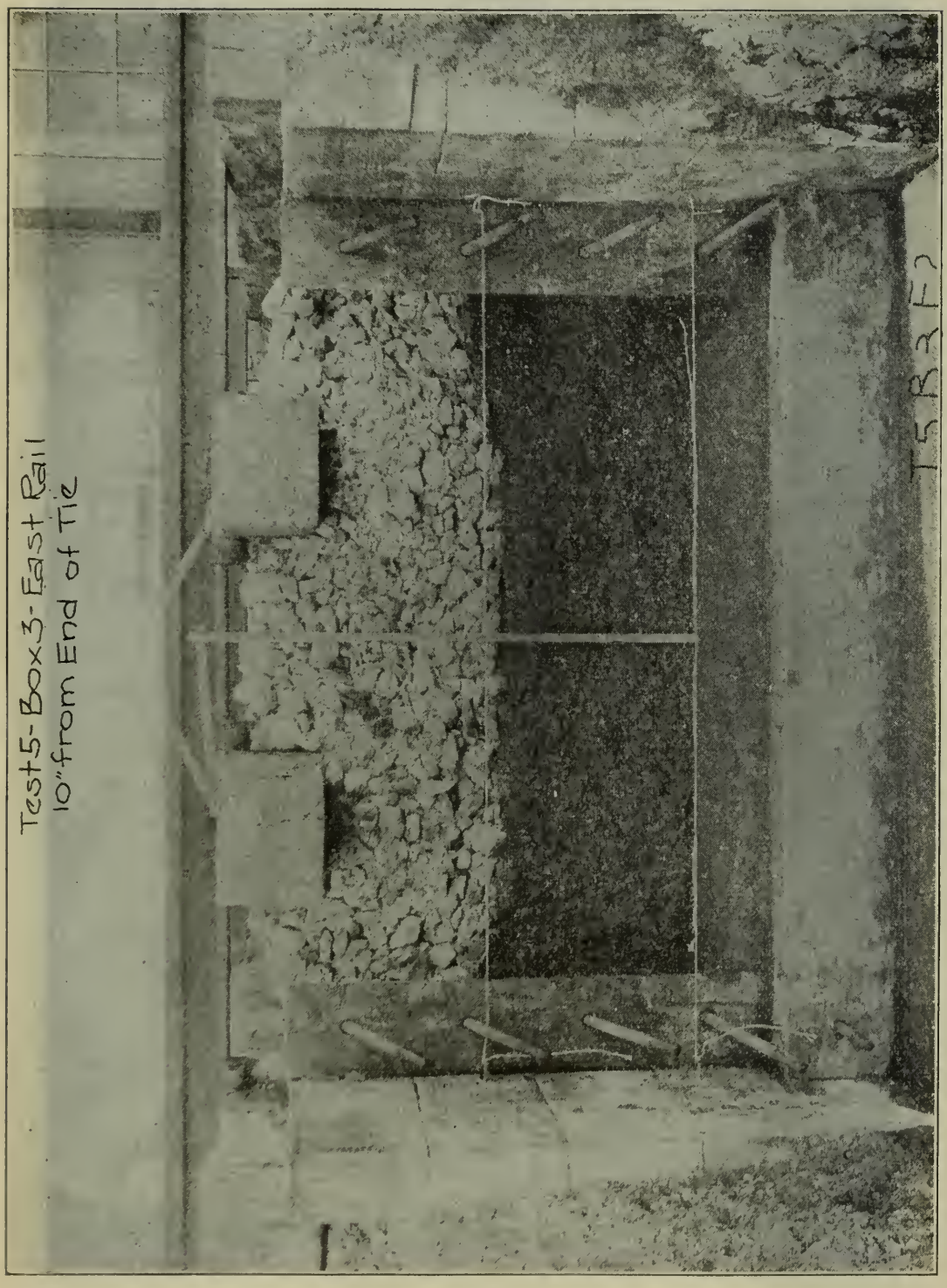

SECTIONS LOOKING THROUGH BOX
5TH. TEST
EAST RAIL
P R R. STANDARD 85 LB RAIL
SOUTH
2'0"
1'1"
P R R STANDARD SQUARETIE
BOX. NO. 2
16½"
7"x9"x8'
WOOD TIE
STONE
CINDER
LOAM
ORIGINAL DIVIDING LINE TRAP ROCK BALLAST
ORIGINAL DIVIDING LINE CINDER BALLAST
INSIDE LENGTH OF WOOD TEST BOX 9' 0"
4' 10½"
8'
2'5"
3'4"

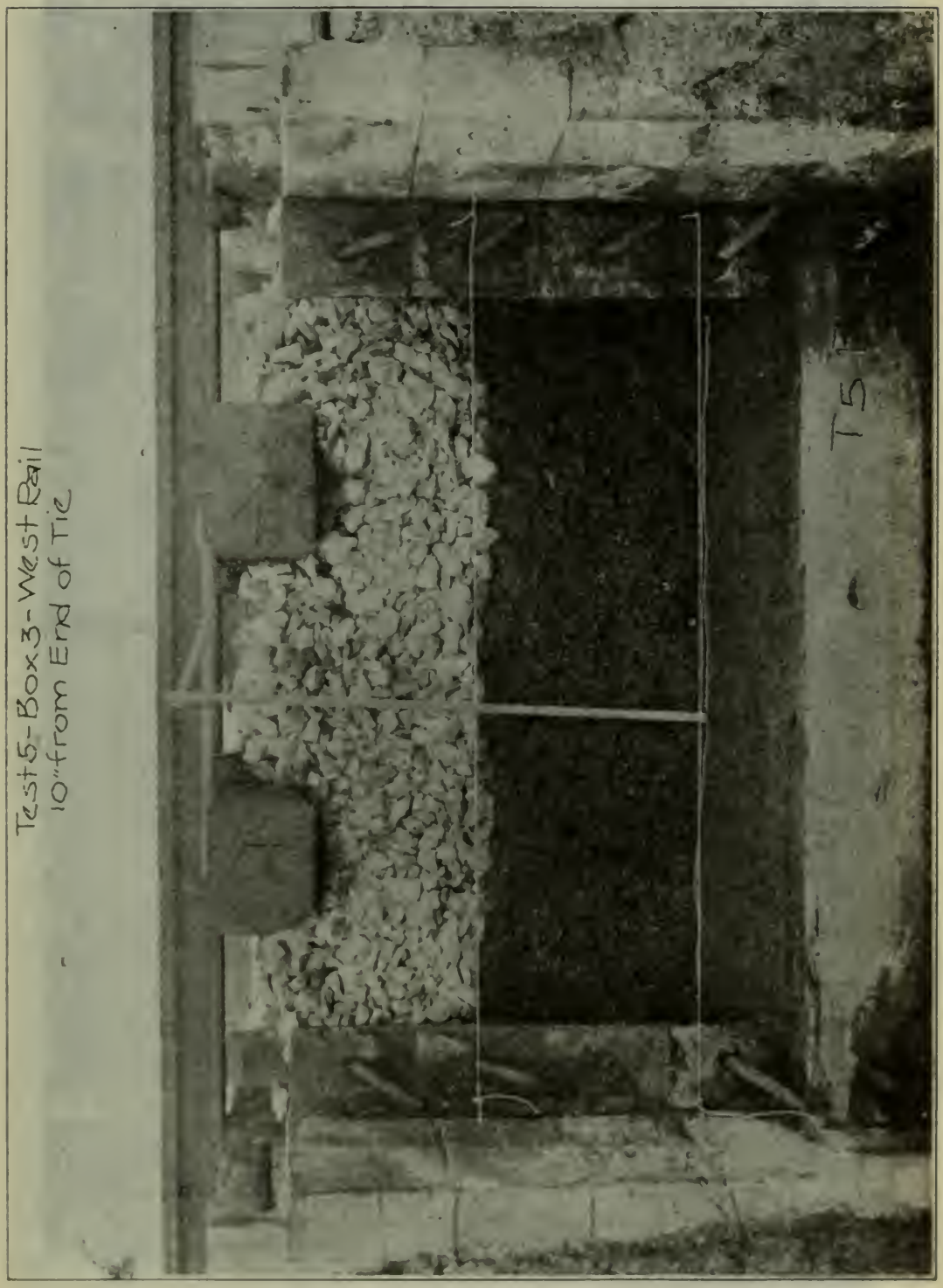

SECTIONS LOOKING THROUGH BOX
6TH. TEST
WEST RAIL
P.R.R. STANDARD 85 LB. RAIL
BOX NO. 2
7"x9"x8½"
WOOD TIE
P.R.R. STANDARD (HEWN) SQUARE TIE
16½"
SOUTH
2'0"
1'1"
STONE
CINDER
LOAM
ORIGINAL DIVIDING LINE TRAP ROCK BALLAST
ORIGINAL DIVIDING LINE CINDER BALLAST
8"
2'5"
SCALE 1"=1'
SEPT. 27, 1910

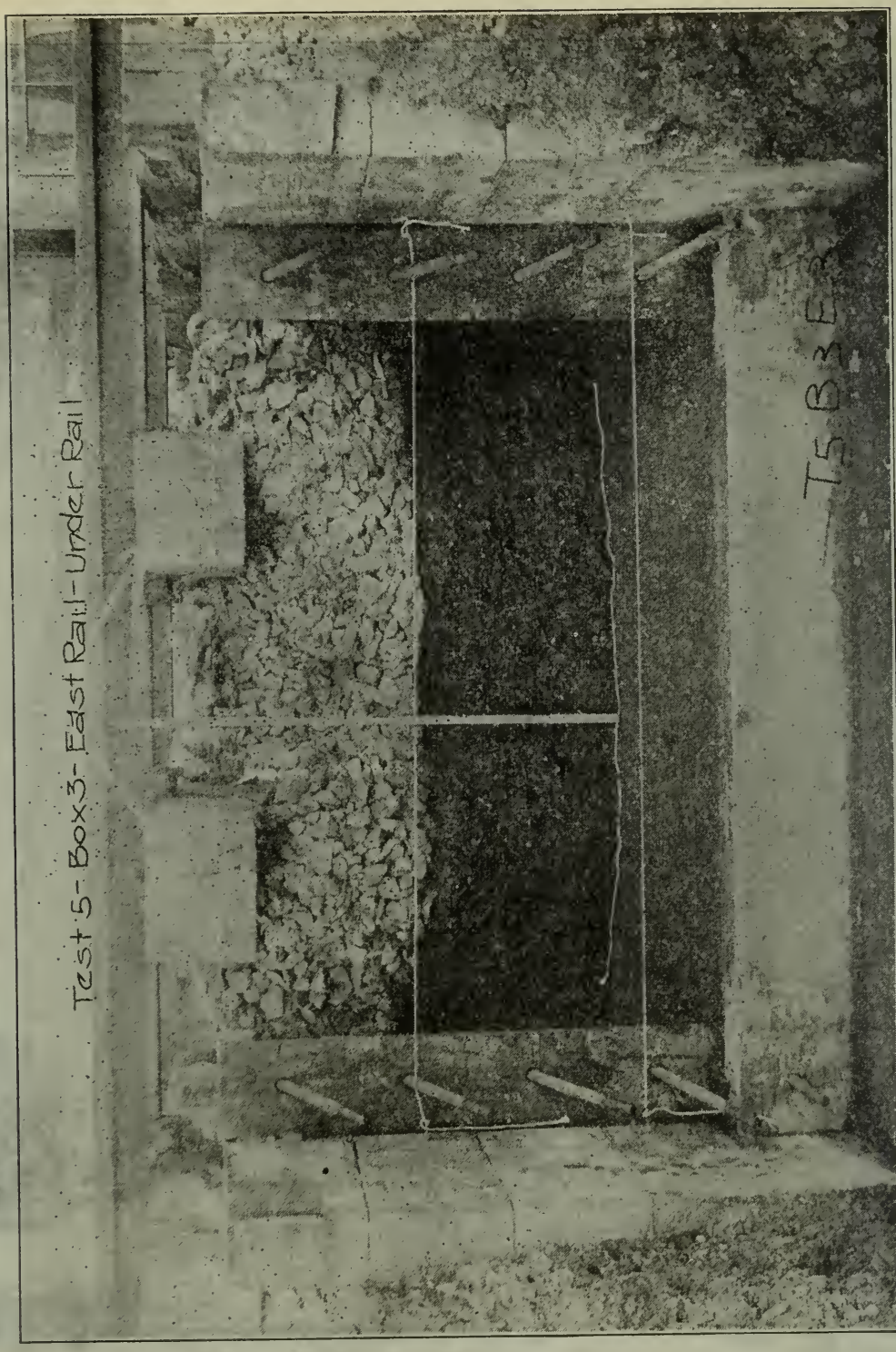

5TH. TEST
BOX NO 2
SECTIONS THROUGH BOX
AT RIGHT ANGLE TO RAIL
EAST RAIL
WEST RAIL
STONE
CINDER
LOAM
90"
LEGEND

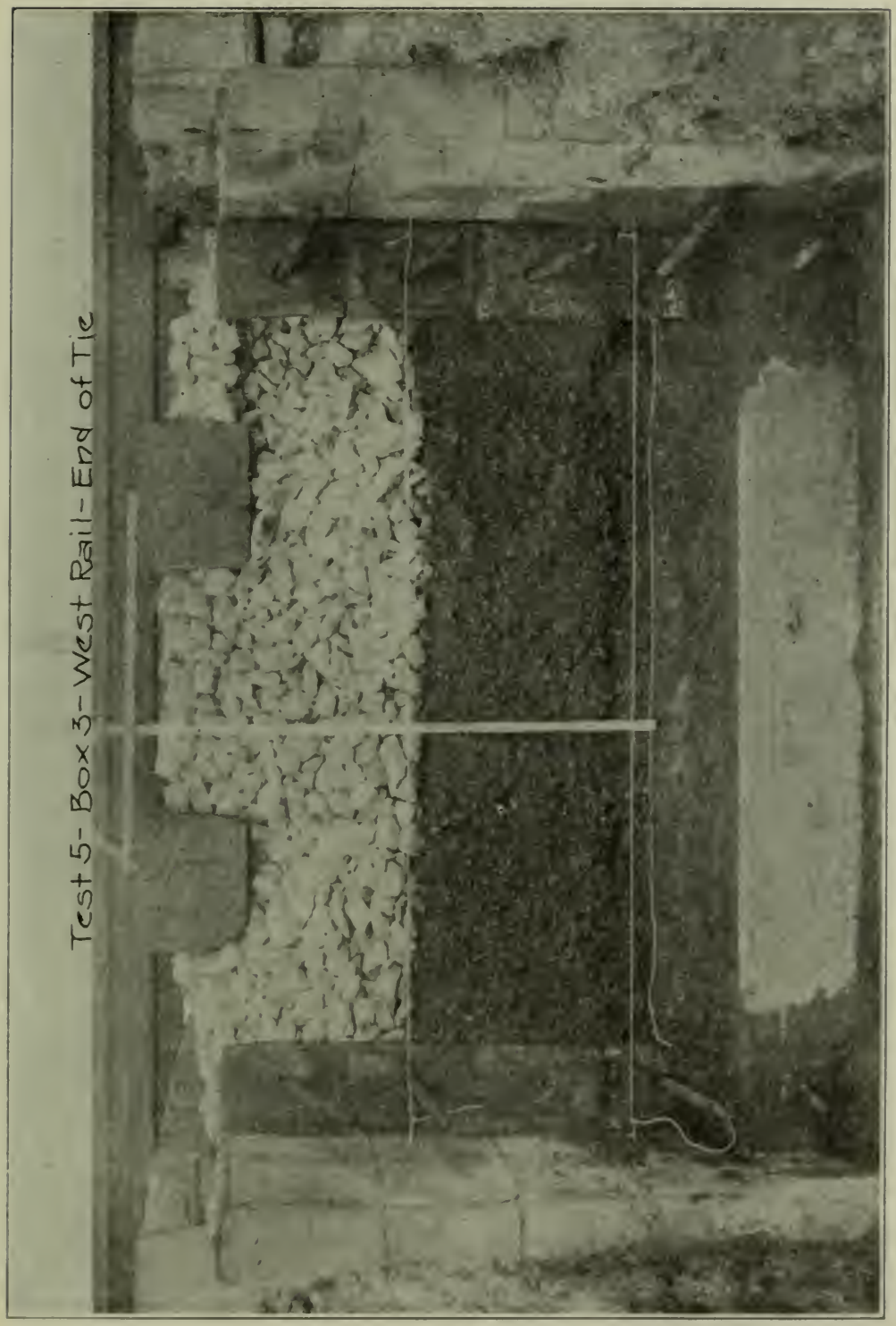

Test 5-Box 3-East Rail-End of Tie
T S

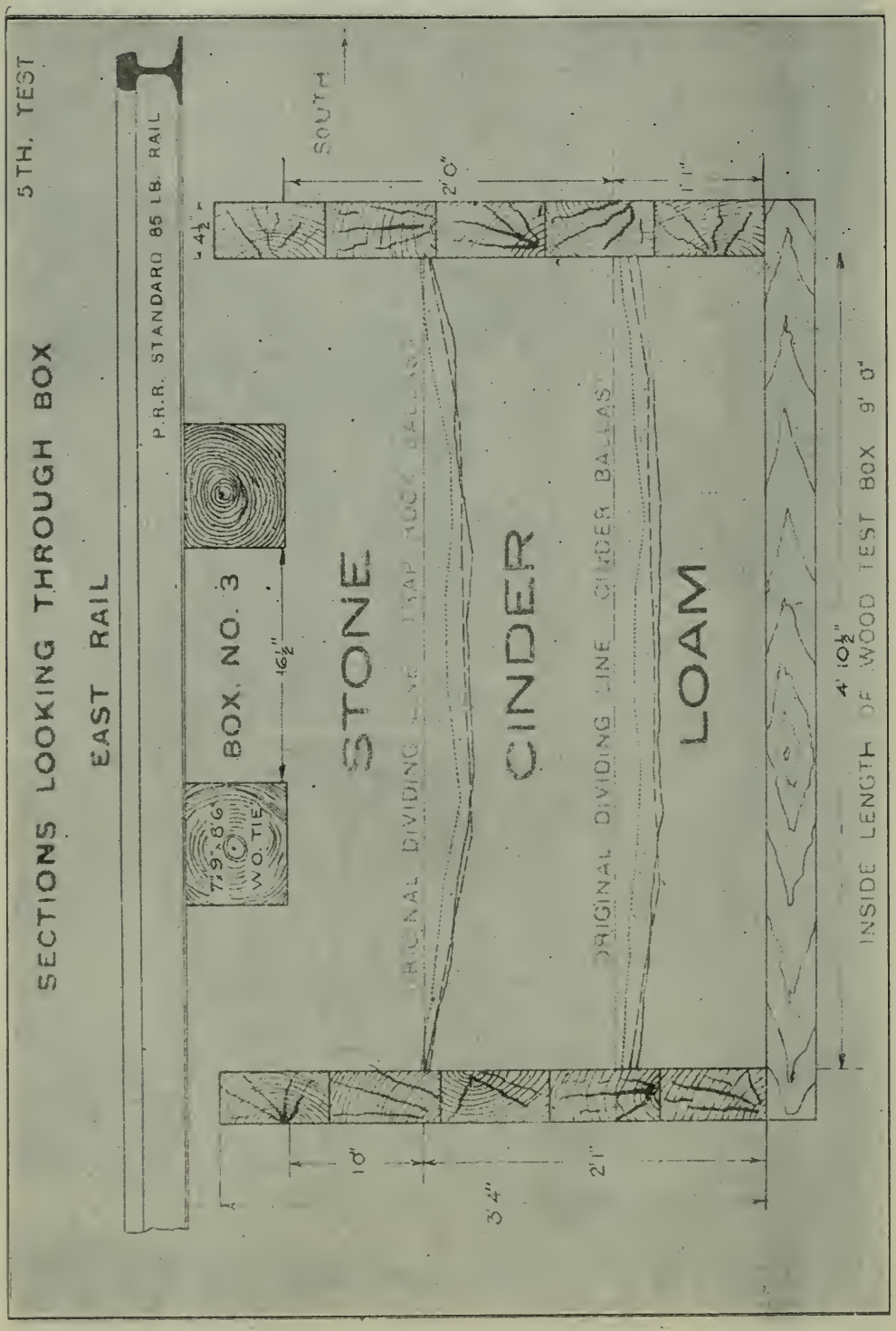

Test 5- Box 3- West Rail- Under Rail

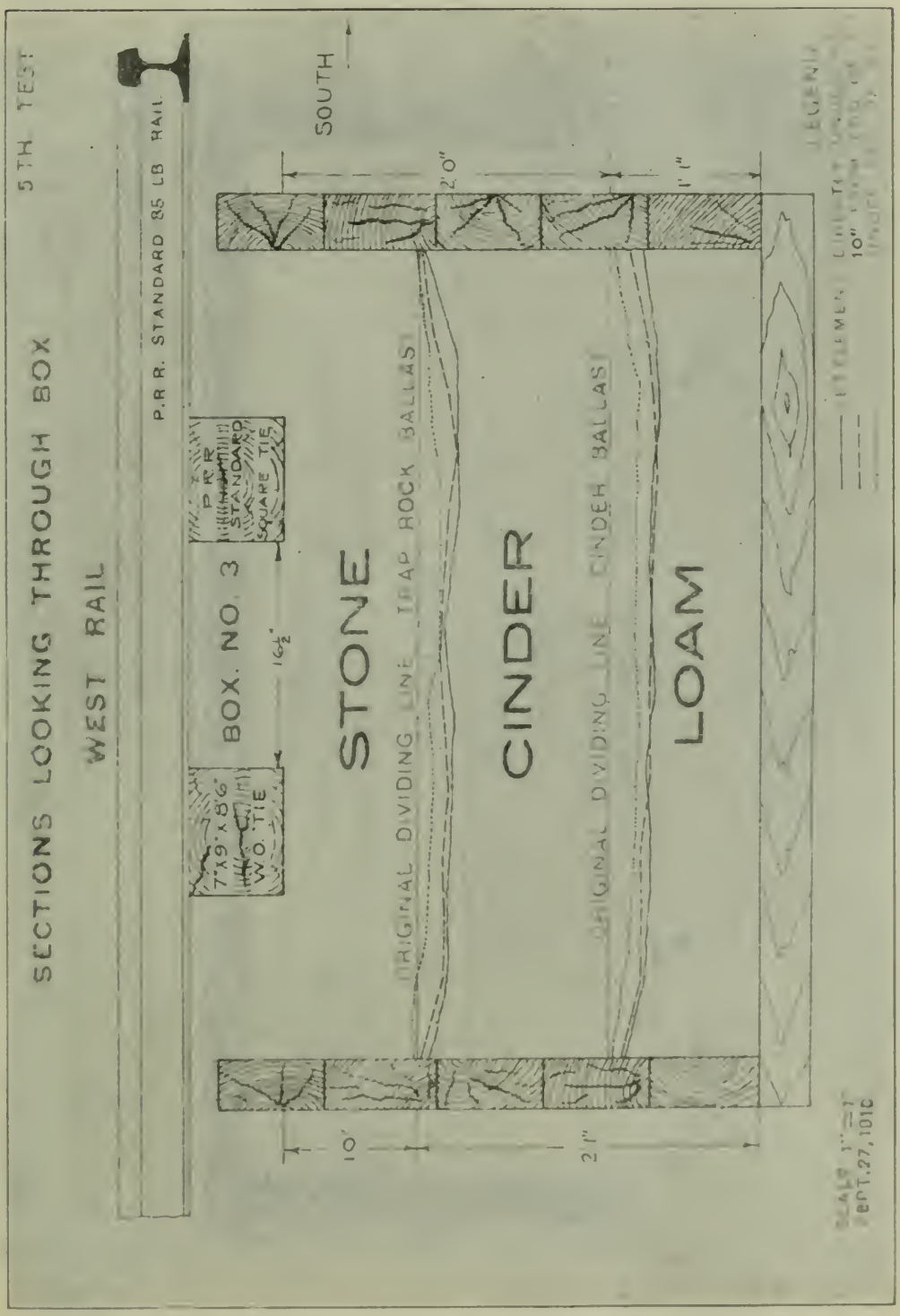

Test 5- Box 3- East Rail
10" from End of Tie
T5R3E2

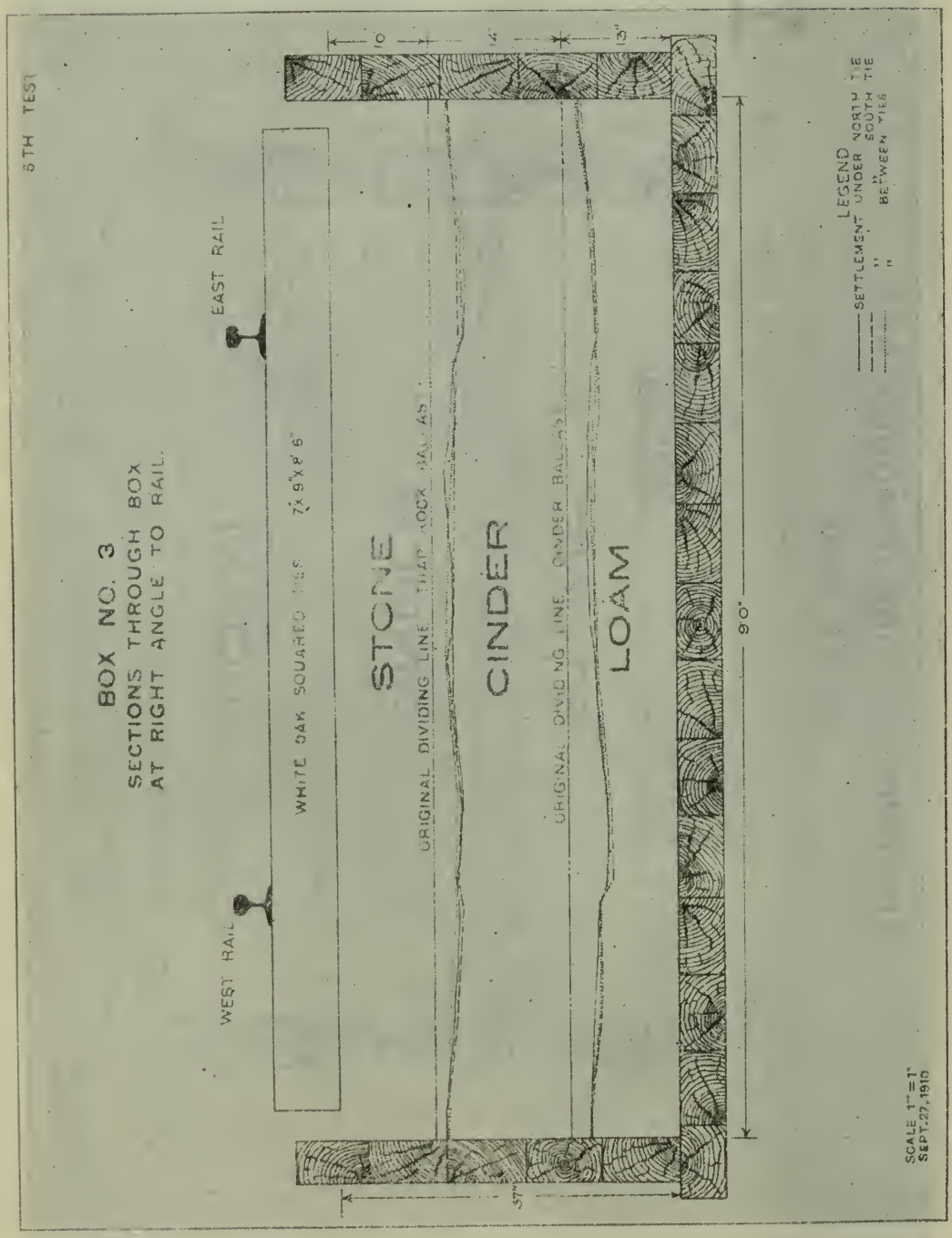

Test 5-Box 3-West Rail
10" from End of Tie
T5

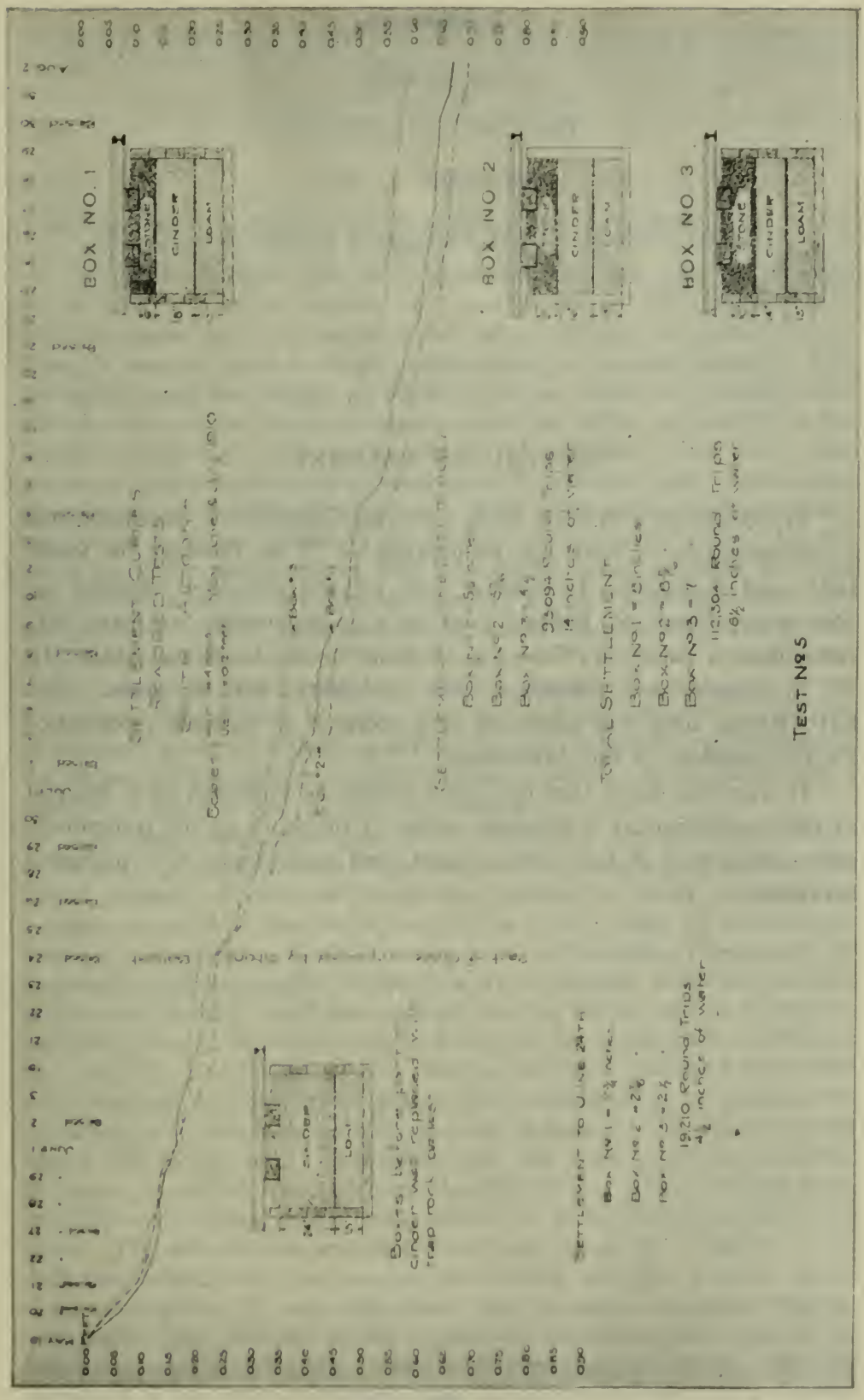

Test 5 - Box 3 - East Rail - Under Rail
T5 B3 E2


Test 5- Box 3- West Rail- End of Tie


SECTIONS LOOKING THROUGH BOX
5TH. TEST
EAST RAIL
P.R.R. STANDARD 85 LB. RAIL
SOUTH
2'0"
1'1"
4½"
BOX. NO. 3
19½"
7-9-86
WO. TIE
STONE
CINDER
LOAM
ORIGINAL DIVIDING LINE CINDER BALLAST
4' 10½"
INSIDE LENGTH OF WOOD TEST BOX 9' 0"
10"
3'4"
21"


SECTIONS LOOKING THROUGH BOX
WEST RAIL
5TH TEST
P.R.R. STANDARD 85 LB RAIL
SOUTH
2'0"
1'1"
BOX. NO. 3
P.R.R. STANDARD SQUARE TIE
7"x9"x8'6" W.O. TIE
16½'
STONE
CINDER
LOAM
ORIGINAL DIVIDING LINE TRAP ROCK BALLAST
ORIGINAL DIVIDING LINE CINDER BALLAST
10'
21'
SEPT. 27, 1910


5TH TEST
BOX NO. 3
SECTIONS THROUGH BOX
AT RIGHT ANGLE TO RAIL.
EAST RAIL
WEST RAIL
WHITE OAK SQUARED TIES 7'6" 9"x8"6"
STONE
CINDER
LOAM
ORIGINAL DIVIDING LINE TRAP ROCK BALLAST
ORIGINAL DIVIDING LINE CINDER BALLAST
10"
14"
13"
90"
37"
LEGEND
SETTLEMENT UNDER NORTH TIE
" " SOUTH TIE
" " BETWEEN TIES
SCALE 1"=1'
SEPT. 27, 1910


BOX NO. 1
STONE
CINDER
LOAM
BOX NO 2
CINDER
LOAM
BOX NO 3
STONE
CINDER
LOAM
TEST N2S

GRAVEL AS BALLAST.

In connection with their work for 1910, Committee I—Roadway, had a sub-committee at work on the question of "Unit Pressure on Roadbed," and Committee II—Ballast, one on the correlated question of "Necessary Depth of Ballast," and at a joint meeting of these sub-committees a paper on "Gravel as Ballast," by C. Bräuning, which Mr. W. M. Dawley had translated from "Zeitschrift für Bauwesen," Vol. LIV, Berlin, 1904, was discussed, and accepted as valuable information for the members of the Association.

It was considered that the paper should be published in a Bulletin of the Association as a progress report of the work of the committees, rather than hold it for a final report, and accordingly it is presented herewith.

Appendix C.

(Bulletin 136.)

GRAVEL AS BALLAST.

By C. Bräuning.

Translated from "Zeitschrift für Bauwesen," Vol. LIV, Berlin, 1904, under direction of Committee I—Roadway, and Committee II—Ballast.

Owing to its high cost, hard stone, crushed, can only be afforded for ballast in roadbeds which are heavily taxed with traffic, while stretches taxed to a less extent must resort, at least for some time to come, to material near at hand, mostly river or mountain gravel. Still, increasing speed and weight of rolling stock on these less severely taxed stretches are making heavier demands upon the ballast, principally in the direction of greater resistance to change of position of the rails. The greater carrying capacity of crushed stone is principally due to the many sharp edges of the individual pieces. This gives it the high resistance when used as ballast, which is not greatly reduced under shock. On the other hand, the gravel pieces give way easily under pressure and lose still further in resistance when subjected to shock. These different characteristics of crushed stone and gravel affect the roadbed, first, in that they determine the cross-sectional shape of the ballast; secondly, the support to be given the track, and, thirdly, the shape and spacing of the cross-ties. While there is ample data at hand regarding the properties of crushed stone as ballast, available through Schubert's investigations, the object of this article is to determine to what extent gravel makes possible a uniform and permanent roadbed.

The observations, therefore, direct themselves first to the conditions to be met. It was desirable to follow out the changes in different individual roadbed stretches and note their greater or lesser durability in comparison with the peculiar characteristics of the ballast of each stretch. Previous observations in this direction were not complete (Zeitschrift für Bauwesen, 1896, page 546). Hence, they were extended, new trial stretches under more varying conditions selected, and the measurements themselves perfected, namely, by more securely anchoring the bench marks outside of the roadbed. The ballast of the observed stretches consisted of a mixture of coarse and fine gravel with a sand content of 25 to 33 per cent., consisting of grains under 1 mm. greatest diameter. The cross-ties were spaced 750 to 840 mm. The traffic over the roadbed yearly amounted to about 1.2 million tons. Among the daily trains which covered these stretches were several which had a velocity of 75 kilometers per hour and more. The observations were continued two years, the elevation of the rails was taken every two months, and during affecting weather conditions more often. It was determined that the most important observations came just previous to the occurrence of, during the time of the heaviest, and just after the complete disappearance of frost. The rail elevations at the above mentioned times are shown in Figs. 1 to 4, Plate I.

The horizontal base line indicates the first observed condition during the autumn, the lines II, III and IV the altered elevations during the severest time of winter, of spring, and of the following fall, respectively. The elevations are to the scale 1=1.166, while the lengths are greatly contracted.

Under each group of observations is a longitudinal section through the track which illustrates the composition of the ballast and sub-soil and the depth of the frost line. The changes observed for the first year and for the second were so similar that the observations for one year only are given.

It is to be noted from the illustrations that close relations exist between the different elevations of the rails and the nature of the soil upon which the roadbed rests. Every clay and clay-bearing soil drove the track upward, and as other observations indicated, also towards the sides. The more uniform such soil is, and the more uniformly it is distributed, the more uniform the tendency to lift the track seems to be, and to lower it again after the disappearance of frost. Fig. 2, Plate I, in its first half, and illustration 1 in its second half give a clear representation of this effect. Irregular mixtures of sand and clay, as occur in earthen embankments such as are formed by dumping led to very unfavorable action in spots, owing to the fact that the earth, due to the action of the frost, was unevenly forced upward and outward and did not by far regain its original position after frost had disappeared (Fig. 4, Plate I). Clean and evenly fine grained sand proved to be quite constant under the action of frost, and a similar absence of the expansive force of frost was noted in the gravel ballast itself, though it was not entirely free from earthy constituents.

During the seasons of no frost such apparent influences of the soil underneath the ballast were not noted. The effect of the deposits, which came principally into consideration here, changed itself according to the water-absorbing capacity of the clay-bearing sub-soil, but the contour of the sub-grade varied within such narrow limits that it was impossible to observe individual changes. In the summer time the sinking of the rails was generally very small and hardly measureable. Several times notice was taken of the rising of the rails up to 2 mm.—however, only at the hottest time of the year.

In order to illustrate more clearly the changes taking place in the rail surfaces in relation to the seasons and the condition of the sub-soils, cross-sectional views illustrating the sinking and rising of distinct groups of the stretches under observation in continuous line for two years are given in Figs. 1a to 4b, Plate I.

Of all the changing lines, those of Figs. 2 and 2b, Plate I, between the points 13 to 18, are of particular importance. The rail and cross-ties here rest on a strong gravel bed, under which clean sharp sand extends to a level lower than the frost line. The ties are spaced 750 mm. and the rails are fastened to them with screw-spikes. The extraordinary permanence and uniform position of this piece of track indicates that gravel

with a large quantity of sand, under proper condition of the sub-soil and construction of the roadbed, will act as very serviceable ballast

A comparison of wooden cross-tie construction was also made with longitudinal stringer construction made up of Haarmann's stringer rails, which, owing to their unfavorable position in the roadbed, are more sensitive to the changes in the ballast and sub-soil than the wooden cross-ties. The results are shown in Figs. 5 to 7, Plate 2. Rail section, as pictured in Fig. 5, stood up comparatively well. The gravel ballast in this case was mixed with broken stone which had formerly been tamped underneath the previously existing longitudinal stringer of the old roadbed. The sub-soil is clean fine grained sand, which in several spots was permeated with clay, whose effect on the roadbed became distinctly noticeable. The section of track illustrated in Fig. 6 seems to be considerably more mobile; in spite of the fact that the roadbed rested on strong broken stone bed of 300 mm. thickness, the influences of the uneven clay-bearing sub-soil made themselves felt the same as with gravel ballast. The most distinct and irregular movements occurred with the track section shown in the second half of Fig. 7, Plate 2, which rested on an ordinary gravel bed, resting in turn on a heterogeneous mixture of clay and sand. The rails were so considerably bent, due to the heaving through frost, that they had to be replaced. (Compare, also, Fig. 7a, Plate 2.)

The harmful influence of frost on the roadbed is increased, due to the fact that the damage resulting therefrom occurs very suddenly, and as long as the frost continues can be remedied only with great difficulty and incompleteness. In connection with this, it is not sufficient to take into consideration only the apparent defects which become noticeable when riding, but also the small, quickly changing, bulging effects which the hard-frozen roadbed is obliged to suffer, due to the minor expansions in the sub-soil, and which defects do not become noticeable when riding over these stretches. For minor localized heavings cause very considerable stresses in the rails, which stresses increase with stiffness of the rail and the rigidity with which it is frozen in the roadbed. High rails which are securely fastened to the cross-ties, which are comparatively closely spaced, are more endangered than weaker rails which rest loosely on the roadbed. The recent construction of heavy rails and narrow tie spacing are well adapted to distribute the load over a greater portion of the ballast, and thereby decrease the demands made on the ballast; but, on the other hand, make increased demands for more regular construction and the prevention of all forceful local disturbances of the form of the roadbed. The nature of the ballast, whether crushed stone or gravel, does not assist in remedying the influences of the soil upon which the ballast rests. In order, therefore, that the sub-soil have no influence on the roadbed, it is necessary that it consist of a material which is constant under the action of frost, and extends below the frost line. In North Germany frost extending to a depth of 70 cm. in loose sand and gravel, or a depth of approximately 55 cm. underneath the wooden ties, should be taken into

consideration. Any bed of clean sand will serve as a frostproof sub-soil, even when the sand is of fine grains.

When the transforming influences of the sub-soil and the weather are removed, the characteristics of the ballast itself come into play. The investigations were continued along the line of determining the effects of these different properties. In purely scientific treatment of the roadbed it is commonly taken that the ballast is uniformly elastic, and this feature only is taken into consideration. As a matter of fact, the different portions of the ballast which act as individual supports are not uniformly elastic. Each load occurring in the operation over the roadbed causes, with the temporary depression, also a permanent change, however slight. This permanent set has a definite relation to the unit pressure imposed. If, therefore, the loads are unequal which are transmitted to the ballast through the ties, then the set underneath the more heavily loaded ties is more serious than in the case of the others. Consequently, owing to this tendency, the original conditions of loading of the ballast are gradually changed, principally in that the pressures under the more heavily loaded ties gradually diminish and the pressures under the lightly loaded ties gradually increase, until the condition of loading becomes quite uniform. In order to observe these phenomena, a section of roadbed was purposely unevenly tamped so that a portion of the ties rested solidly on the ballast, while the other portion was without any support. By repeated observations it was found that the spaces between the ballast and the ties gradually diminished, and after six months disappeared entirely. This is shown in Fig. 8, Plate 2, in which the spaces measured at different times between the tie and ballast (scale 1=1.166) are indicated by cross-hatching. Hence, ballast supporting cross-ties not uniformly loaded tends to change itself into a uniformly loaded mass. Of course, this equalization of the loading does not occur through a uniform sinking of the rail and ties, but is due rather to more or less prominent local depressing, and thus amounts to a deterioration of the condition of the roadbed.

An equal change is experienced by the ballast underneath each tie. And here, too, the tendency is for the tie to take such a form that the unit pressures of it in the ballast are equal in all places. Hence, the tie itself becomes a beam with uniform loading, and the surface of the ballast underneath the tie assumes, therefore, the shape of the elastic curve of the tie under this particular condition of loading. This shape of the surface is present whether the tie is loaded or not (Fig. 1). But since the passing loads are not uniform, and hence the unit loads on the ballast vary, the shape of the surface of the ballast becomes the average of the elastic curves of the tie due to the different loadings. In making this statement it is assumed that the resistance of the ballast is equal at all places. If this is not the case, then those placed where the resistance is not so great as in others will give way until all places are loaded in accordance with their resistance. This appears regularly as the case

underneath the ends of the cross-ties, of which mention will be made later on.

The continual changing of the form of the roadbed is a result partly of the compression of the ballast, and also, perhaps to a larger extent.

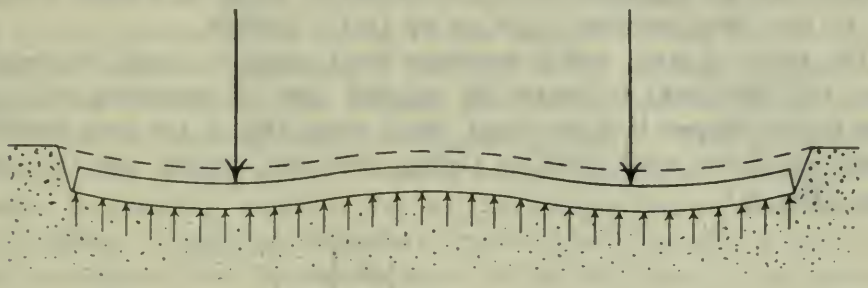


Fig. 1.

the result of a sidewise spreading. The loading of the bed under and next to the ties is so continually at variance that an equalization of the pressure cannot take place and the lightly loaded part between the ties is continually being displaced by the heavily loaded part underneath the ties. The possible shapes of these sidewise spreadings are treated theoretically in Dr. H. Zimmermann's "Berechnung des Eisenbahnoberbaues," page 108. Thus it became desirable, by means of experiments, to get an idea of the actions as they really took place. For this purpose, therefore, dry sand of different colored layers was poured behind a pane of glass, and after a picture of the sand was transmitted to the glass, it was loaded down with ties 30x60 mm., so that distinct displacements occurred in the sand bed. By comparison with the original position of the different layers, the paths of the sand grains under increasing loads could clearly be traced. The occurrences which took place in this experiment, and which were repeated several times, were as follows: After the sandbed was entirely compressed by the imposed load, a sidewise displacement of the sand

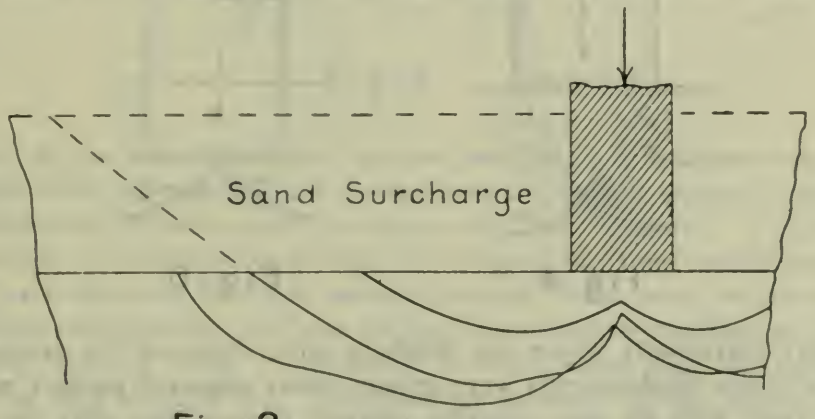


Fig. 2.

began, first in lines which were not distinct, then becoming more distinct, until eventually very pronounced lines of separation appeared. Several of these lines are shown in Fig. 2. Although they diverge considerably in

their longitudinal relation to one another, due to the variation of the internal friction, nevertheless the theoretical basic shape of the logarithmic spiral is recognizable in their curvature. The shape of the lines of separation is not changed when the ballast is piled up higher than the ties; in fact, they continue right on up to the surface.

The body of sand, which separates itself, tends to retain its original shape, and also seeks to regain the original lines of separation when the tie is forced deeper into the sand, since when this is the case resultant resistances of the sand particles sliding over one another are at a minimum (Fig. 3).

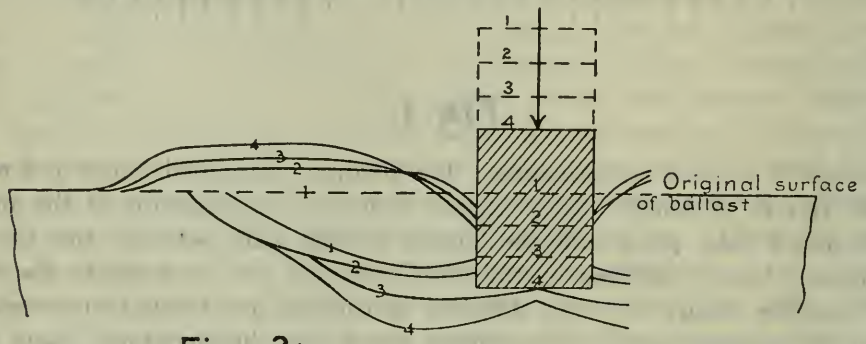


Fig. 3.

Underneath the tie the separation of the sand layers did not appear as uniformly and distinctly as above. At the start of the experiment, a slender wedge would usually form, with its apex pointing downward. This wedge would become more blunt as the tie sank deeper into the sand, and the location of the apex remained comparatively firmly fixed, so that the lines of separation, extending from the sides, retained their original position, as is pictured in Fig. 4. On the other hand, however,

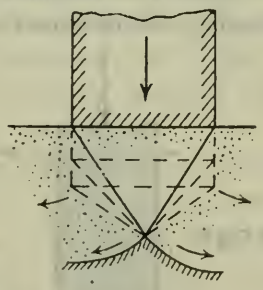


Fig. 4.

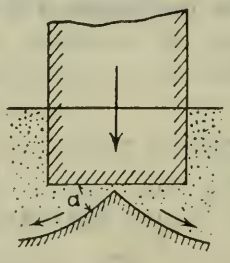


Fig. 5.

and more particularly where the sandbeds were deep and the resistances to the sidewise displacements were greater, there appeared another wedge, firmly fixed, with its apex pointing upward, from whose sides the sand particles would glide (Fig. 5). This tendency of the particles to glide from the sides of the upturned wedge continues so long as the angle "A" (Fig. 5) stays larger than the angle of repose of the material under experiment, for as long as this condition continues the particles of material

which are being forced seek the path of least resistance and adopt the next and steepest path to the surface.

Hence, it is not a case of dealing with a distinct shape of separation, but rather with the nature of the external resistances to these shapes, which oppose internally the motion of the material. The free development of the bodies of separation is hindered in the roadbed by the close spacing of the cross-ties. The integral parts of the bedding which move grow less, but the internal resistance becomes greater. When the sandbed is gradually narrowed, a point is reached where the escape of the particles no longer is possible, which is due to the equalization of the internal surface-rubbing resistances and the imposed load. At this point these internal resistances vary in amounts equal to the variations of the imposed load. The line of separation in the case of the limited bed approaches the semi-circle, as observed several times and as its limiting shape assumes the form as shown in Fig. 6. Such a shape, as determined mathematically with the coefficient of friction of sand, is then only possible when the unit pressures grow from the edges towards the center of the tie. As a matter of fact, it is readily observable that the center of the tie will seat more firmly than its edges when driven into narrowly confined sandbeds.

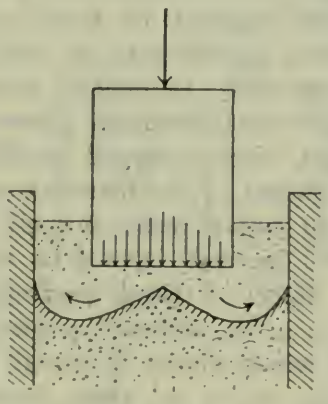


Fig. 6.

Now, if the bed upon which the tie is imposed is confined between two rigid walls, the resistance of the bed with these walls strongly opposes the tendency of the bed material to become displaced upwards. But if the confinement of the bed arises from the neighboring ties, simultaneously loaded, as is the case in track, moving particles which meet between the ties oppose one another, and, not finding any confining resistances, drive themselves upward. Fig. 7 illustrates an experiment with two equally loaded ties on a confined bed. The distances between the ties chosen were such that the amounts of material between the ties and between the walls and the ties were equal, and thus also making the resistance in the two directions equal. This was approximately the case when $a/2 : c = 1 : 1.3$. (Fig. 7.) The distance between ties when the bed material ceased to rise up between them appeared to be when $a = 1.5b$. Even with a pressure

as great as 40 kilograms per square centimeter no rising of the bed material was noted when the ties were brought closer together than a=1.5b.

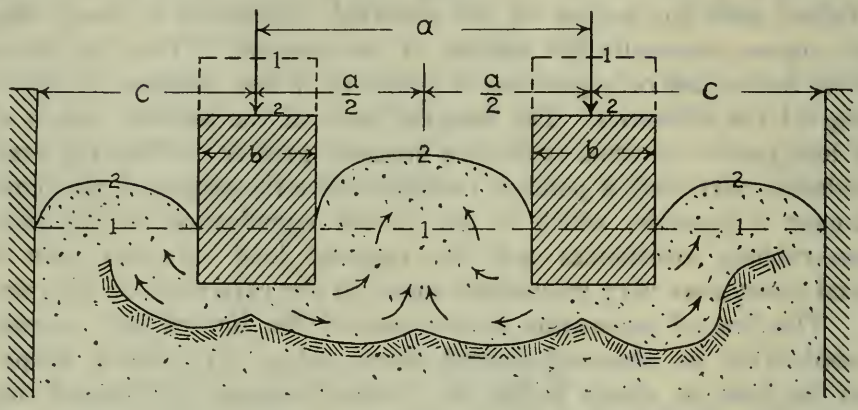
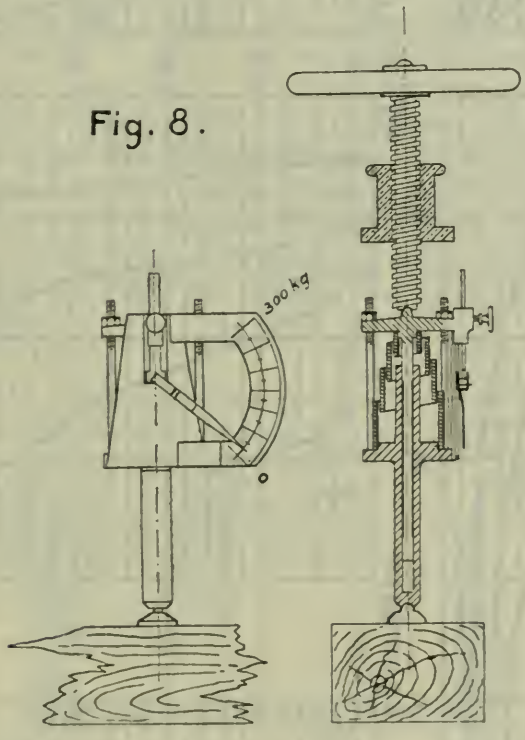


Fig. 7.

After these observations of the nature of the movements taking place in a gravel bed, it became desirable to learn more about the resistances which the gravel opposes to these movements. The heavy pressures required in these experiments do not occur in the ordinary roadbed, so it became necessary to depend upon special arrangements on a smaller scale. The results herefrom cannot be applied directly to ordinary roadbed practices, since enlarged conditions, such as occur in practice, would alter the shapes of the material under load; and, further, since the varying nature of ballast material itself and peculiarities of the loading in actual roadbed practice cannot be taken into consideration sufficiently. Hence the object of these particular experiments was to determine certain relations of the different properties of the ballast material which it is assumed would obtain in actual practice. More particularly speaking, it was the object of these investigations to determine the influence of tie-spacing, the width of ties, the height to which material was packed between the ties, and of the nature of the ballast itself. For the purpose of these experiments iron cases with adjustable walls were used. They were of such a depth that the movements of the materials in the bed would not extend to the bottom. A press consisting of a screw and a heavy spiral spring, which transmitted the pressure imposed upon the spring to an indicating pointer, was used to load the tie (Fig. 8). The scale of the indicating device was determined by means of actual weights. The press was arranged for a pressure as high as 300 kilograms, but by means of a lever, which could be coupled in, it was possible to raise the pressures up to 500 kilograms. The ties which were used had a width ranging from 10 cm. to 80 mm. The bed consists of dry pit gravel, made up of rounded grains, up to 5 mm. in diameter. No larger particles were used, since it was desirable to prevent hollow formations in the gravel bed, owing to the diminished scale which was being used.

The first experiments were made on single ties ranging in width from 20 to 60 mm., resting on a bed of fine grained sand, no particles of which exceeded 1 mm. in diameter. The pressure was increased until clearly defined movements were discernible in the bed. As a rule, a sudden collapsing or release occurred when the pressure reached a certain point temporarily relieving the pressure imposed. The resistance of the bed depends upon its width "a" (Fig. 9), the width of the tie "b," and the height to which the bed material rises along the side of the tie "h." The influence of the width of the bed "a" bears a particular relation to the width of the tie "b." Hence, this influence may be designated by the relation a/b, through which may be determined the proper tie spacing. The results of the experiments are demonstrated in Figs. 9a to 9c. In Fig. 9b the distances between ties are plotted along the abscissa, while the carrying

Fig. 8.



capacities of the bed in kg. per sq. cm. are plotted along the corresponding ordinates, giving curves for different heights of "h" ranging from 0 to 30 mm. When h was 0 and the relation between a/b was greater than 7, the carrying capacity remained practically constant. As the distance between ties decreased the carrying capacity increased, first slowly and then more rapidly, so that when a/b=2 it was twice as great as when a/b=3.

The carrying capacity was further increased as gravel was piled up between the ties. The influence of the spacing was partially compensated by the increasing height of the material between them to the extent that the carrying capacity was equal in ties spaced narrowly without mate-

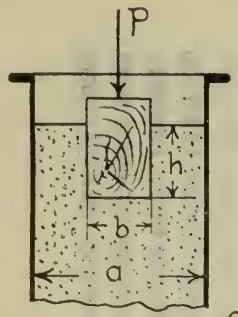


Fig. 9 a.

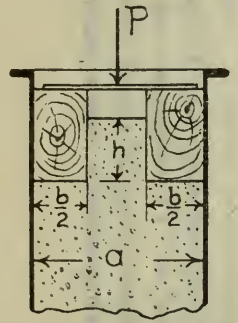


Fig. 10 a.

Fig. 9 b.

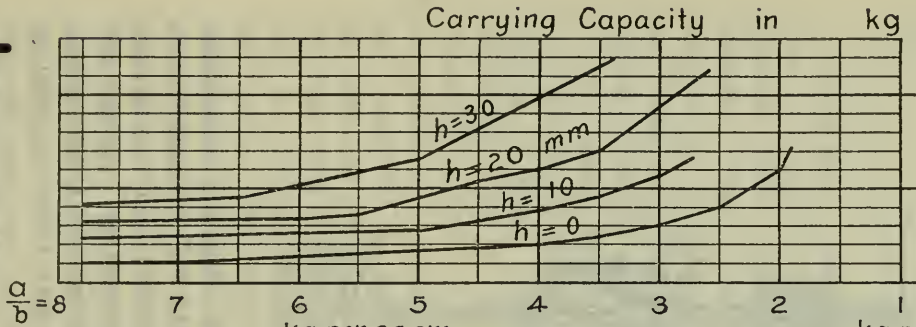
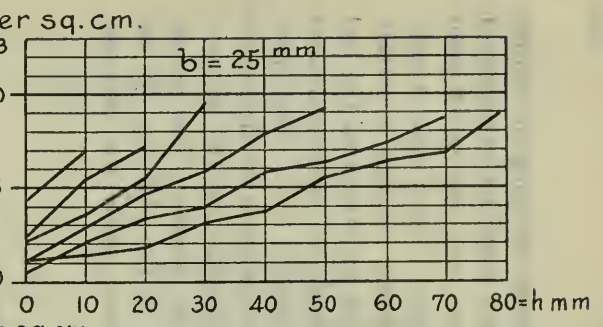


Fig. 9 c.



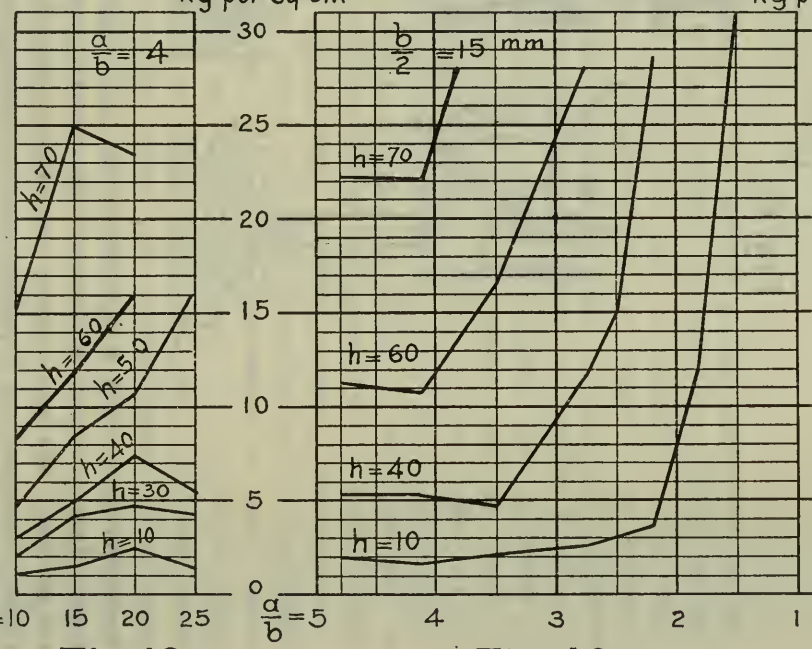


Fig. 10 b.

Fig. 10 c.

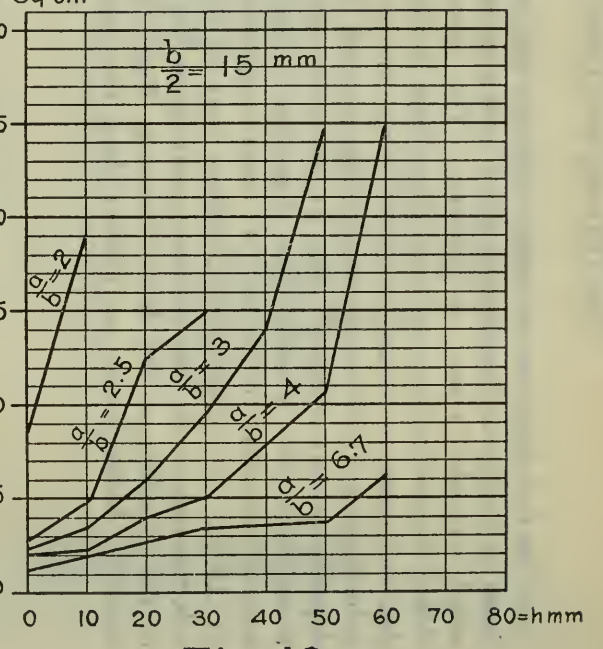


Fig. 10 d.

rial between them to ties spaced widely with material packed between them. The effect of the height to which material is packed between the ties is particularly demonstrated in Fig. 9-c. The several lines are for tie separations ranging for a/b from 2.6 to 20, while the height to which material was piled between ties, ranging from 0 to 80 mm., are the abscissæ, and the carrying capacities are the ordinates.

Positive determinations of the action of the widths of the ties could not be made from the above results. So in order to get at the actual conditions prevailing in a roadbed, where ties are equally and simultaneously loaded, two ties were rigidly bonded together and placed into an iron box, so that each came very close to the sides of the box (Fig. 11). In order to reduce the friction of the bed material on the walls of the box, they were lined with glass. Since the ties fitted into the box so that three sides of each tie were contiguous to the sides of the box, the only possible escape for the bed material was between the two ties. The width of the ties in reality, therefore, corresponds to ½ the width of a tie in actual practice, and, consequently, is indicated by b/2. At this time it was observed that a wedge with its apex pointing upward appeared underneath each tie when the material between the ties had reached a certain height and the material of the bed tended to glide off the sides of this wedge, exercising a heavy pressure sidewise on the tie. The size of the gravel particles ranged from 1 to 2 mm., the width of the ties b/2=10 to 50 mm., the height to which the material was piled between the ties extended up to 130 mm.

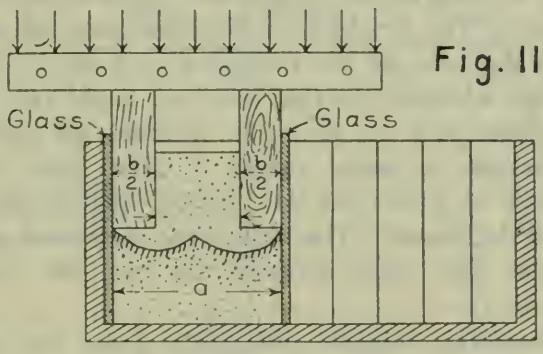


Fig. 11.

The results illustrated in Fig. 10-a to 10-d are similar to the ones reached in previous experiments; however, the effect of tie spacing was felt at lower values of a/b, approximately when same equaled 4 (Fig. 10-c). As this ratio decreased its influence was still greater than in the previous case, so that the carrying capacity with a ratio of a/b=2 was four times as great as when a/b=3. The limit was reached for a sidewise displacement of the bed material when a/b=1.5 and h=10 mm. As the height h increased, the carrying capacity of the bed, it seems, grew at an increasing rate (Fig. 10-d). These relations were the more apparent and more effective as the distance between ties decreased. Here, also, a distinct influence of the width of the ties was noticeable on the carrying

capacity of the bed, as is demonstrated in Fig. 10-b for different values of h, height of material between ties. As the widths of ties increased the unit pressure increased according to the laws of a straight line, maintaining a relation quite constant. An increase in carrying capacity is also proven for this case in Dr. H. Zimmermann's "Berechnung des Oberbaues," page 115.

The experiments thus far did not attempt to deal with any different loading except those free from shock. Hence, the effect of a load in connection with shocks still remained to be investigated. When ballast is subjected to impact the friction of the gravel particles rubbing against one another is temporarily diminished. Gravel ballast, therefore, when subjected to this condition, behaves as a bed which is loaded fixedly and whose angle at repose is more flat. In order to approach conditions as they occur in an actual roadbed, the ballast was subjected, by means of a loaded lever, to a uniform pressure of 1.5 kg. per sq. cm. The case containing the bed was subjected to vibration or impact through a weight which dropped each time from the same height. The number of impacts in the time that the tie sank 10 mm. into the bed was taken as the measure of resistance of the material. As a rule, the tie started in to sink faster at the start of the experiments, but its rate of entering soon became uniform. The width of the ties was from 39 to 87 mm., and the height to which the bed material was piled extended in some instances to 300 mm. The illustration indicated in Figs. 12a and 12b again reveal a distinct relation with previous results. The effect of the spacing again became noticeable when a/b=10, and became more apparent when a/b=4 and less (Fig. 12c). The height to which the material was piled along the side of the tie also affected the resistance in a similar way (Fig. 12f). The meaning of the width of the ties was also made very apparent, as is demonstrated in Figs. 12-b to 12-d for different tie spacing. The resistance of the ballast increased rather a trifle faster than would be indicated by the law of a straight line, under equal pressure, as the distance between ties decreased. The closer the ties were spaced, and the higher the material was piled between the ties, the more rapid this increase became.

The ballast, however, behaved differently under the ends of the ties than elsewhere. Similarly, as demonstrated above, a body of material tends to separate itself underneath the end of the tie. But since there is no other tie to oppose this displacement, the ballast terminating on a slope, the opposition of this sideward tendency of the gravel underneath the end of the tie is comparatively small. Hence, the carrying capacity of the tie at its ends is less than at its center, but it increases from the ends toward the center of the tie until it reaches those points from each end where the resistances sidewise and outward towards the ends are equal. Between these points the carrying capacity is uniform. Since the support given the tie bears a direct relation to its carrying capacity, the pressure underneath the tie on the ballast diminishes outward from the two points described above. The closer the ties are spaced, the greater

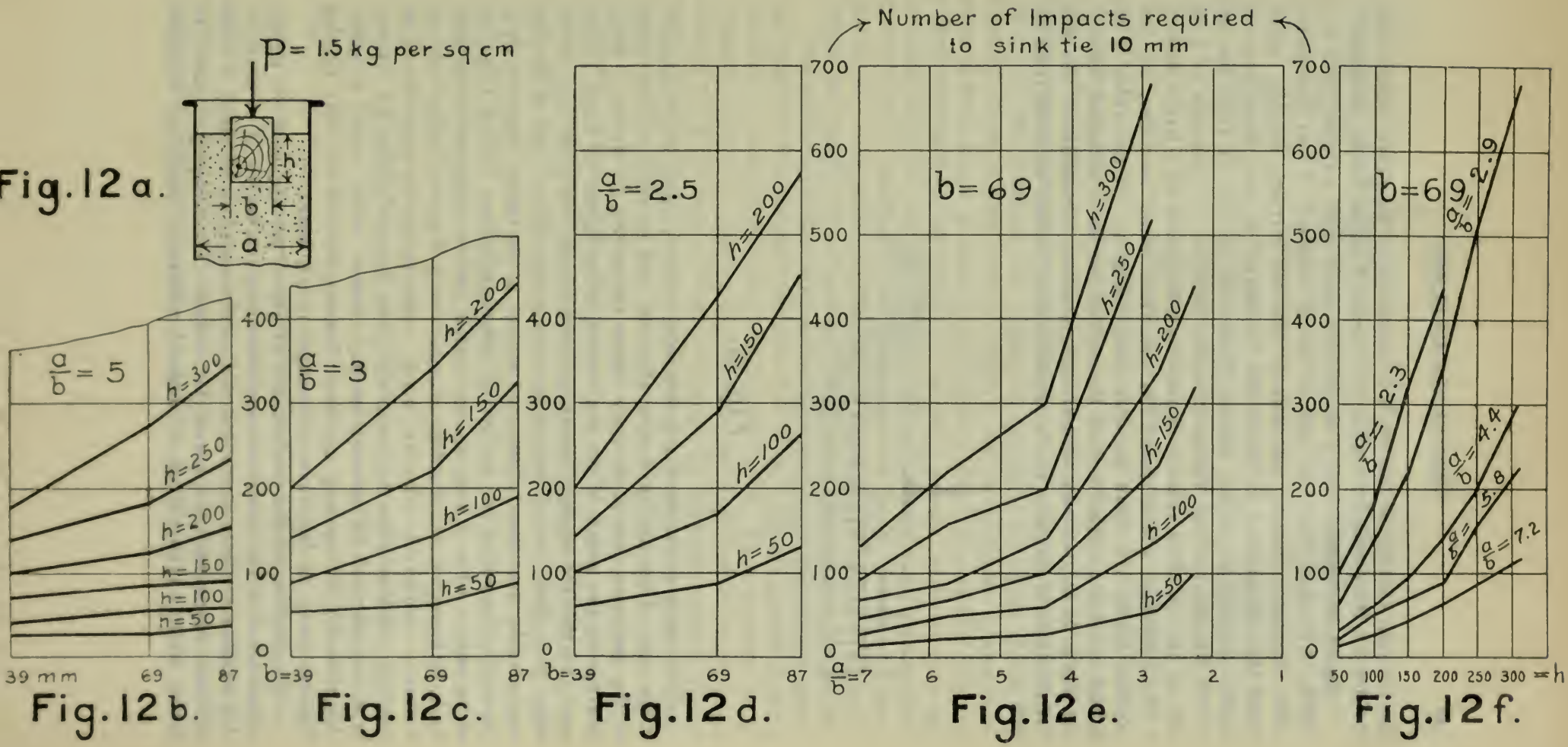


Fig. 12 a.

Fig. 12 b.

Fig. 12 c.

Fig. 12 d.

Fig. 12 e.

Fig. 12 f.

the carrying capacity of the roadbed becomes, and the nearer to the ends the ties are, the points from which the pressure on the ballast decreases.

By an experiment with a tie 50 mm. wide, with material piled to a width of 60 mm. from the end of the tie outward, it was determined, when the space relation was a/b=3, that the carrying capacity underneath the extreme end of the tie was 0.4 kg. per sq. cm., increasing uniformly towards the center until a distance of 45 mm. in from the end of the tie was reached, thence becoming uniform at a pressure of 4 kg. per sq. cm. If these relative dimensions are applied on a larger scale to a tie of 260 mm. width, spaced 780 mm. from center to center, the proportions which will result are illustrated in Fig. 13. If the width of the ballast extending outward from the end of the tie is unlimited, then C, the length of the territory of decreasing pressure, diminishes to 180 mm., but increases to 400 mm. in the absence of any ballast outward from the end.

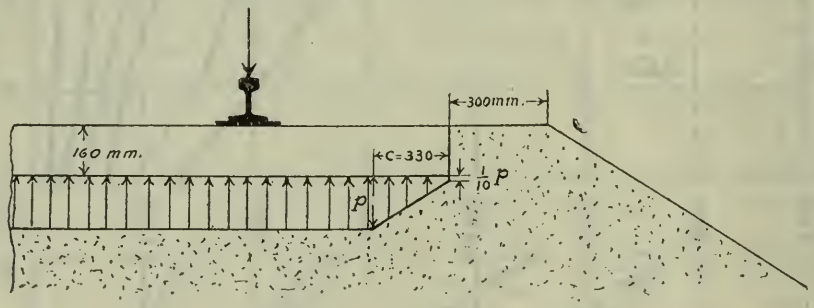


Fig. 13.

The length of the tie has no influence on the relation of the pressure at the ends of the tie, but it does affect the load intensity and the length of the uniformly loaded territory under the middle of the tie. When determining the length of the ties, consideration should be taken, on the one hand, that the bending moments do not become too great, and, on the other, that lightly loaded portion, or portion carrying no load, is properly supported by the ballast. Since the surface of the ballast adapts itself to the elastic line of the tie, a short tie, when not loaded, will be supported at its middle, while a long tie, not loaded, will be supported at its ends. And, furthermore, the bending moment of a long tie under the rail increases considerably with its length, which should be taken into consideration with wooden ties, especially when wooden dowels are screwed in at the place of the greatest bending moment, which would considerably diminish the carrying capacity. Consideration of all those limiting features seems to determine a tie length of 2.8 meter.

The question of the smallest size of gravel particles and the largest admixture of foreign material permissible in gravel ballast is of considerable significance, from a practical and economical point of view, to those railroads depending upon gravel for ballast. The carrying capacity of gravel depends primarily on its internal resistances, which are indicated

by the angle of repose of material. For ordinary dry gravel, the following values are determined:

Number.	Size of Grains.	Angle of Repose.
I	Less than 1 mm.	31° 11′
II	1 mm. to 2 mm.	33° 45′
III	2 mm. to 3.1 mm.	36° 9′
IV	3.1 mm. to 4.2 mm.	37° 10′
V	4.2 mm. to 5.6 mm.	40° 15′
VI	5.6 mm. to 9.2 mm.	39° 48′
	Mixture of I, II, VI=1:1:5	34° 35′
	Mixture of II, IV=1:1	36° 52′

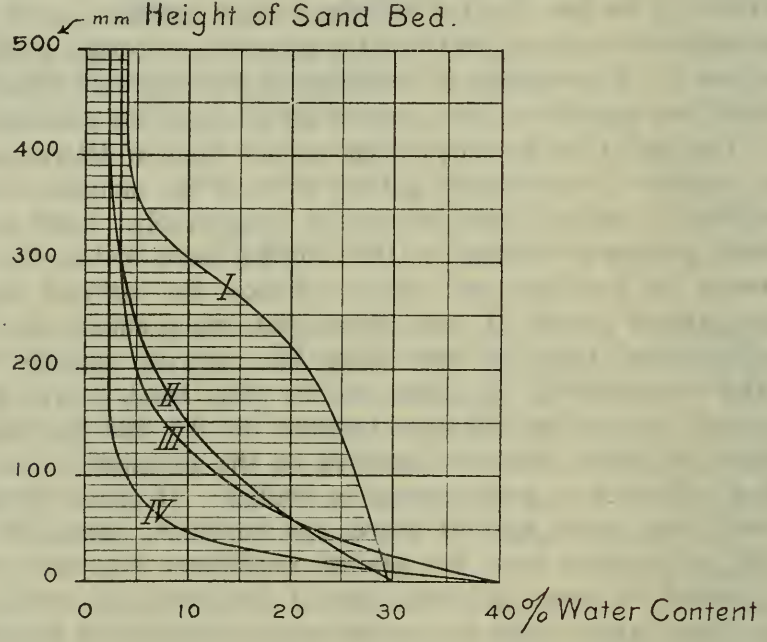
Hence, the angle of repose increases from 30 to 40 degrees, with increase in size of the grains. According to the theoretical investigation of Dr. H. Zimmermann's "Berechnung des Oberbaues," page 116, the carrying capacity of the bed increases very rapidly as the angle of repose of the bed material increases from 30 to 40 degrees, and at 40 degrees it should be three to five times as great as at 30 degrees. Now, if experience does not substantiate such a great variation in carrying capacity, consideration must be taken of the fact that the internal friction decreases when the materials are subjected to shock, and that the presence of foreign material is apt to increase it. Experiments to determine if coarse gravel subjected to heavy impact was superior to fine grained gravel were not conclusive in results

The size of the gravel particles are not alone in determining the carrying capacity of the material, but the effect of the moisture present and the condition of material also influence it considerably. Light moisture, as is usually present at the base of the roadbed, tends to increase the adhesion between the particles, and, hence, enhances the carrying capacity of the finer grained gravel. It was found that fine grained gravel in a moist condition had twice to four times the carrying capacity of the same gravel in a perfectly dry state; on the other hand, coarse grained gravel revealed no striking difference between the dry and the moist stage. A surplus of water, however, loosened up the adhesion of the finer grains when subjected to quick change in loading. If proper drainage is provided, then coarse grained gravel can hardly be saturated with water; while, on the other hand, fine grained gravel may easily be saturated, since it retained the water up to its point of saturation. In order to determine the rate at which water is absorbed and again released by gravel, the following experiments were made:

In a watertight box, 500 mm. high, dry sand was piled of a size not exceeding 1 mm. Water was then poured in until it reappeared on the surface. The absorption of water amounted to 29 per cent. of the volume of the sand. The surface water was then drained from the sand through a series of tap holes, spaced 50 mm. apart, and measured. It was determined that the amount of water drained at the top was comparatively small, it was increased as the depth became greater, and became fairly constant after a depth of 400 mm. had been reached. The reason for this phenomenon appears to be that the capillary attraction in the upper layers

when the water level is high preponderates, but as the same sinks the attraction decreases. Furthermore, the fine streams of water, as they flow downward by their own weight, draw water from the upper layers as long as they will release it. When the highest layers have become dry, this phenomenon continues downward, as each tap is opened.

The diagram, Fig. 14, represents, by the area bounded by line I and the X and Y axes, how the water content varied from the top to the bottom of a bed 500 mm. deep. The original water content of 29 per cent. decreased from the bottom towards the top to 4 per cent. Similarly, lines II, III and IV of this same Fig. 14 illustrate the variation of the water content of different gravels made up of coarser grains as designated under the diagram. The water-absorbing capacity of the coarser gravel was greater than that of the finer gravel, but the release of water, as the level sank, was more rapid. In fact, gravel of greater than 2 mm. was practically free from moisture at a height of 130 mm. above the level of the water. The moisture finally retained after the gravel had been drained ranged with the different sizes between the narrow limits of 2.5 to 4 per cent.



I Size of grains less than 1 mm.
II Pit Gravel with 25% of grains less than 1 mm.
III Size of grains 1 to 2 mm.
IV Size of grains 2 to 4 mm.

Fig. 14.

Hence, it becomes apparent that coarse gravel, though of comparatively shallow depth, readily drains itself and becomes dry; but, on the other hand, the retained water is practically the same for fine and coarse

gravel, provided there is sufficient depth. The disadvantages of fine gravel in this respect may be mitigated by deepening the roadbed. Consideration must always be taken of the possibility of supersaturation of fine gravel, owing to slower draining capacity under continued rainfall. This may also occur when the roadbed begins to thaw, and the surface water, which is released first, can find no outlet into the lower layer, owing to their continuing in a frozen condition. On the other hand, the tendency of the ballast to remain frozen under the ties, and so form a solid bed for them until sufficient time has elapsed for the portion of the ballast between the ties to thaw, drain to a considerable depth and become dry, is an advantage.

The principal requirements for a permanent and uniform roadbed with gravel ballast may, therefore, be summed up as follows:

The sub-soil upon which the roadbed rests should consist, to a depth of the frost line, of a material which is not affected by weather conditions, nor, when frozen, heaves upward, thus disturbing the ballast.

The continued settling of the rail bears a distinct relation to the internal resistances of the ballast. Hence, ballast, as far as it is subjected to such forces, should consist of material which is uniform in its carrying capacity. When the carrying capacity of the sub-soil, therefore, is not high or varies greatly, as is the case with all earthy soils, the roadbed should be of such strength that the individual loads on the ties are evenly distributed throughout the ballast and uniformly distributed over the sub-soil. Furthermore, all sidewise and circulating movements should be confined within the ballast.

In order to meet these requirements, a depth of bed of about 550 mm. underneath the ties would be sufficient, provided some particularly unfavorable conditions of the sub-soil did not make a greater depth necessary. A clean sand, readily permitting water to pass through it, would act well at the bottom of this bed. The actual depth of the ballast should not exceed 300 mm. underneath the ties in order to prevent mixing with the bottom layer of sand. Regarding the size of the gravel grains, it is desirable, in order to secure a ballast which drains readily in its upper layers, and in order to prevent the undue formation of dust underneath and following trains, and in consideration of the future increase of fine grain content due to tamping, to prevent as much as possible the admission of fine grained particles in the ballast. This, however, only means particles less than 2 mm. in size. As a matter of fact, a mixture of fine and coarse grains is desirable, since it permits of a more solid packing of the gravel underneath the ties than when only coarse gravel is used. But, due to the moist condition of gravel, it is not very convenient to segregate the fine particles from the coarser. In order to accomplish this separation, large coarse screens must be used. This results in a loss of a large and useful portion of the gravel, and the part remaining is often so little that the advantage gained by sifting is not warranted, due to the great expense involved. Under these conditions, therefore, gravel with a 25 per cent. content of grains 1 mm. or less in size becomes practicable, as long as the

conditions are not extraordinary and require an especially strong roadbed.

The width of roadbed bears a certain relation to the length of ties and the spacing of the ties. It is considered that an extension of the ballast outwards from the ends of the tie, with their usual length of 2.7 to 28 m., amounting to 300 mm., is sufficient.

As the height to which the ballast is packed increases, the carrying capacity of the roadbed increases. Hence, material should be piled between the ties as high as operating conditions will permit.

The width of the tie is also of considerable importance, since with constant load the unit pressures on the bed are reduced as the area of the tie increases, and the carrying capacity of the tie increases directly as its area. A general use of larger wood ties is not permissible, owing to the high purchase price and the greater difficulty of obtaining the same. It is desirable to have the ties 2.8 m. in length. Strict consideration should always be given the proper and uniform spacing of ties and shaping of the roadbed in order to utilize to the limit the resistance of the roadbed.

Of greater importance than the width of the ties is the spacing of the ties. As the spacing is decreased two advantages are derived: first, the unit pressure decreases; secondly, the carrying capacity of the roadbed is increased. It is just within the limits of tie spacing usually considered that the relation a/b, ranging from 3½ to 2 (spacing 900 mm. to 500 mm.), that the carrying capacity increases at a high rate. (Figs. 9d, 10c, and 12e.) The limiting feature of decreasing tie-spacing is the ability to tamp the ties properly. Ties 160 mm. in height can still be tamped with convenience when separated 350 mm. But this (the relation being 2.3), 600 mm. from center to center, is the lowest limit. This is the one most effective and simplest means of increasing the strength of the roadbed, and to utilize it to the fullest advantage, especially on roadbeds which are fully loaded, is urgently recommended.

The portion of the ballast under the joints requires special consideration, since the impact at these points makes extraordinary demands on the roadbed. It has been attempted several times to strengthen this part of the ballast by packing crushed stone underneath the ties supporting the joint, however without success.

Another way, and the one usually resorted to in order to accomplish the above, is to bring the two ties supporting the joint as close together as possible, 500 mm. from center to center. The closer the ties are spaced outside of this particular territory supporting the joints the less the difference is between the carrying capacity of the roadbed underneath the joints and the carrying capacity of the rest of the bed. In order to further strengthen the roadbed underneath a joint, it would be effective to increase the width of the ties supporting the joint. For instance, if the width of the ties used is 300 mm., and the distance between them from edge to edge is 250 mm., then the relation between them is 550—300=1.83, as compared with a relation of 600—260=2.31 for the ties not underneath the joints. By means of this decrease in the distance between the ties at the joints, combined with the increased width, as well as the distribution

of the load over greater surfaces, the carrying capacity of the roadbed underneath the joints is increased approximately 75 per cent. Since, as ties are ordinarily furnished, there is considerable variation in sizes, and hence there should be no difficulty in selecting a sufficient number, approximately 10 per cent. of the proper width, to arrange underneath the joints for the above purpose.

As a further means of distributing the shock at the rail joints, methods of combining the two ties underneath each joint by the use of a framework are being tried out.

All means to increase the resistance of the ballast to impact will not be complete and sufficient to properly maintain the necessary support and steadiness of the whole roadbed as long as impacts, due to the passing traffic, at the rail joints continue to vary on account of the varying distance between rail ends, variation in the surface elevation of two abutting rails, wear of the rails and wheel flanges, and other changes in shapes which result in varying shocks. Hence, the question of a proper support for the rail joints is primarily a question of the proper joining of rails with the object of preventing low and loose joints.

Elevations of the Rails

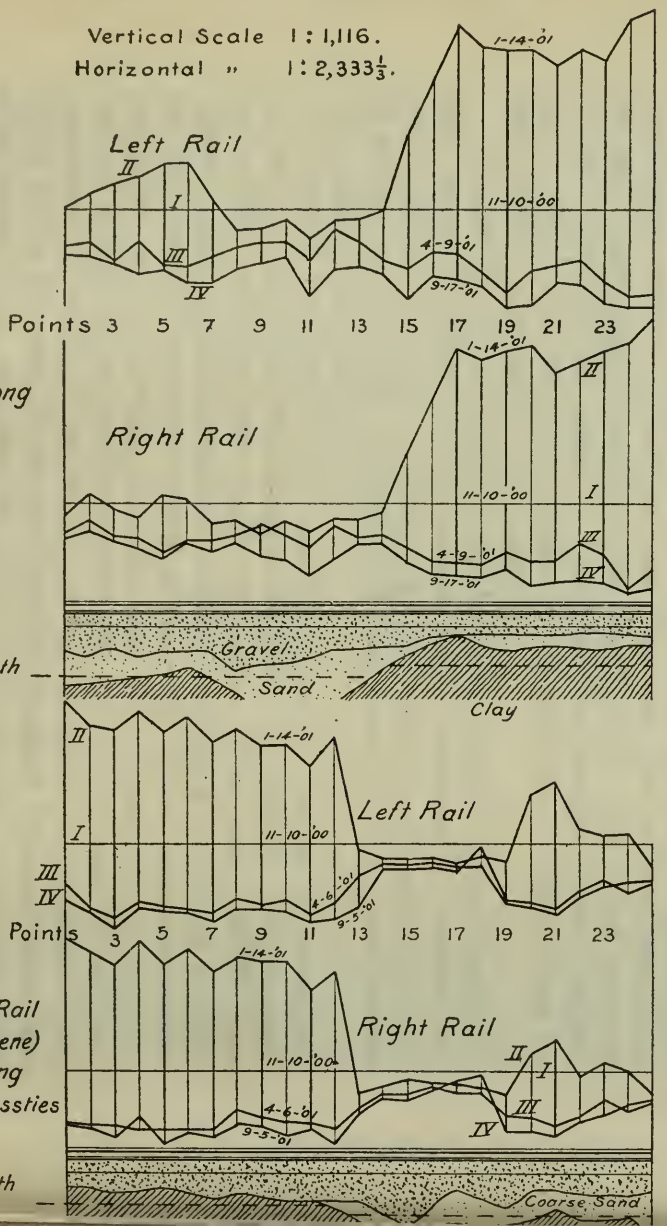
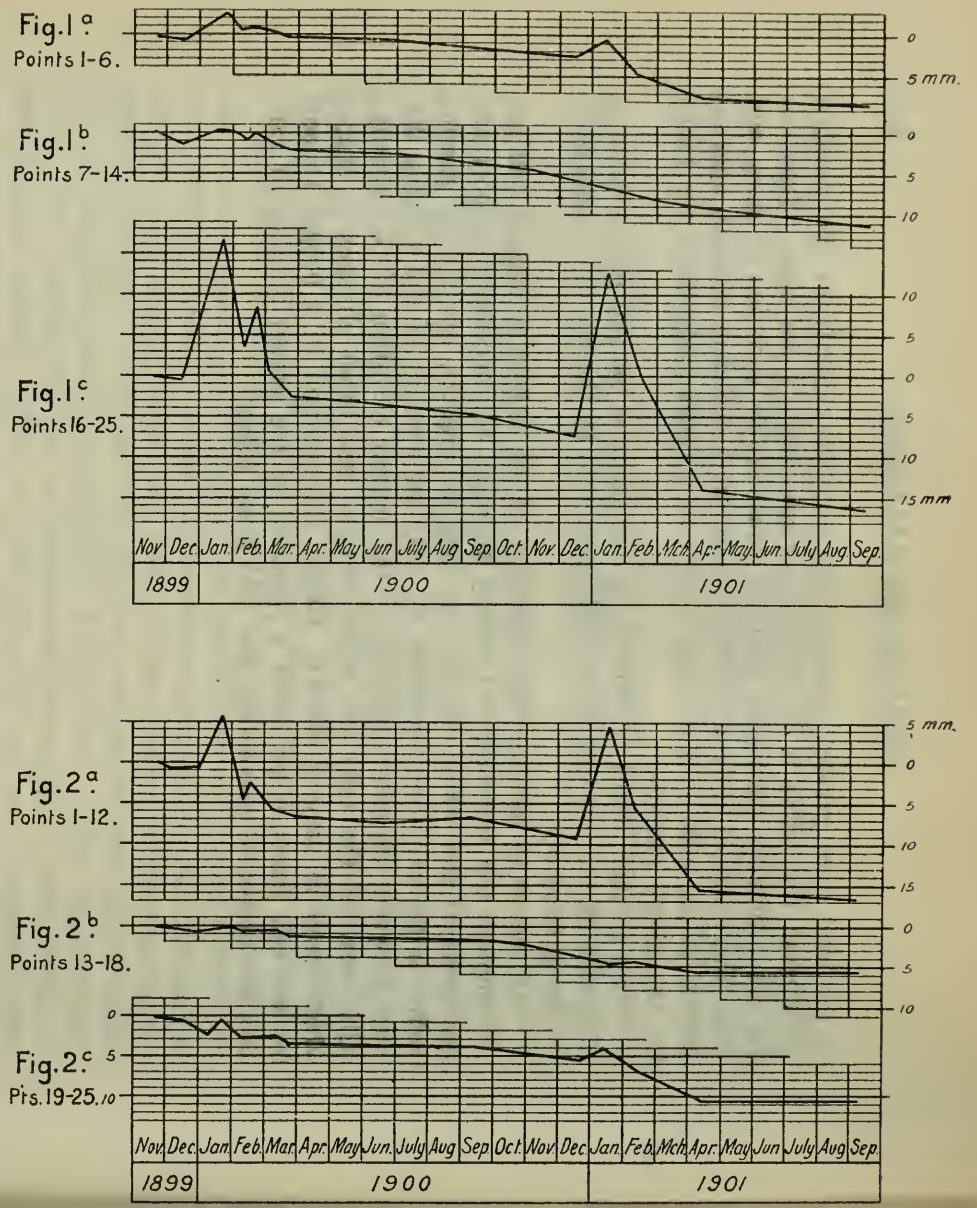


Fig. 1.
Rail 12 meters long on 16 wooden crossties

Fig. 2.
Supported Joint Rail (Blattstoßschiene) 15 meters long on 20 wooden crossties

Average Line of depression of the Rails.



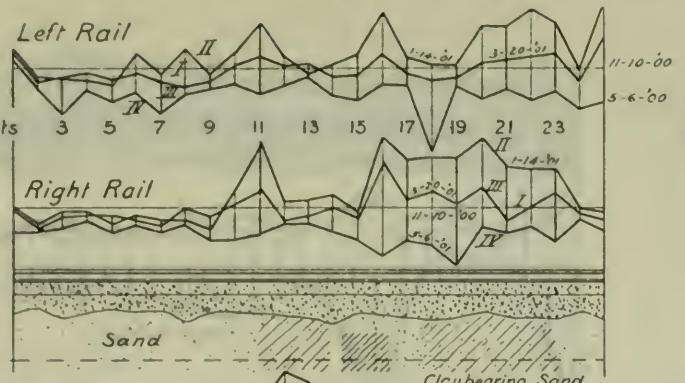


Fig 3

Rail 9 meters long on 11 wooden crossties

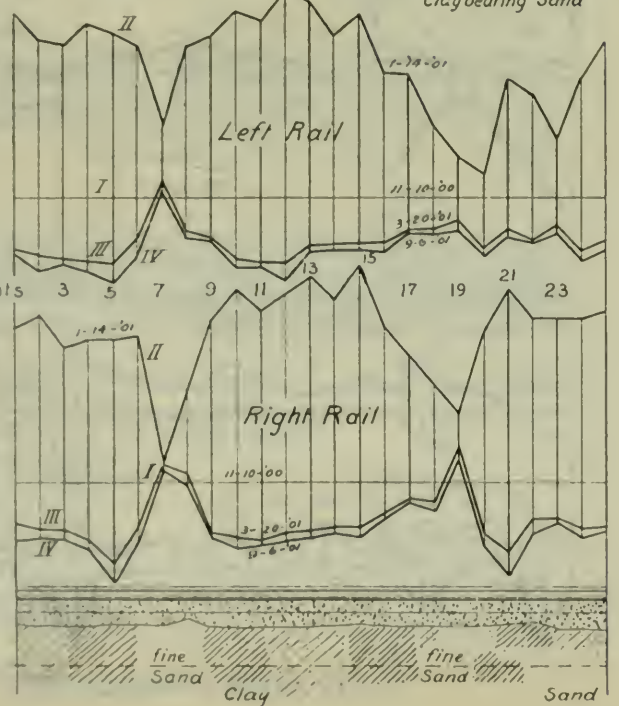


Fig. 4.

Rail 9 meters long on 11 wooden crossties

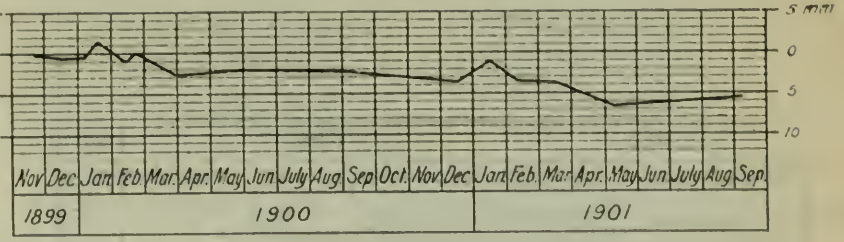


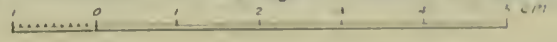
Fig. 3ª
Points 1-25.

Fig. 4ª
Point 7.

Fig. 4ᵇ
Points 8-16.

Vertical Scale for the Longitudinal sections of the Roadbed.

1:116 2/3



Elevations of the Rails

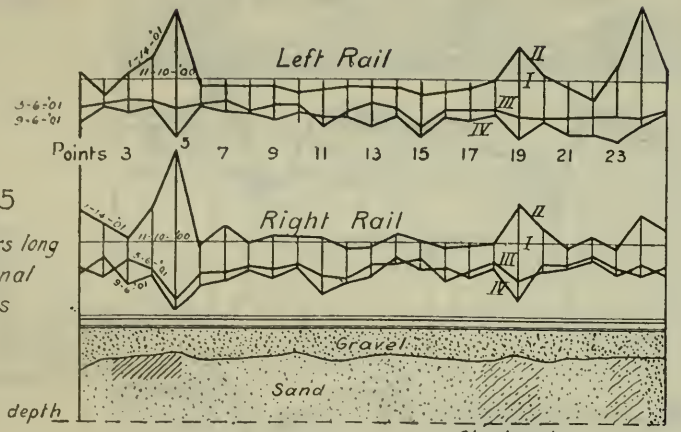


Fig. 5
Rails 9 meters long on longitudinal stringers

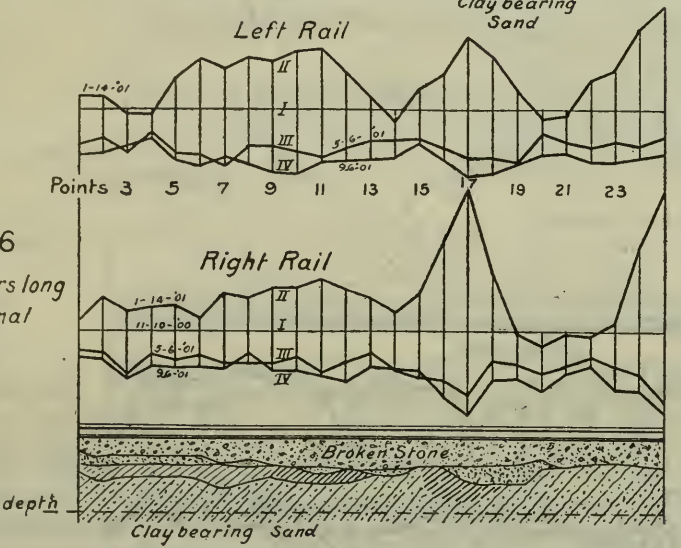


Fig. 6
Rails 9 meters long on longitudinal stringers

Average Line of depression of the Rails.

Fig. 5a
Point 5.

Fig. 5b
Points 1-25.

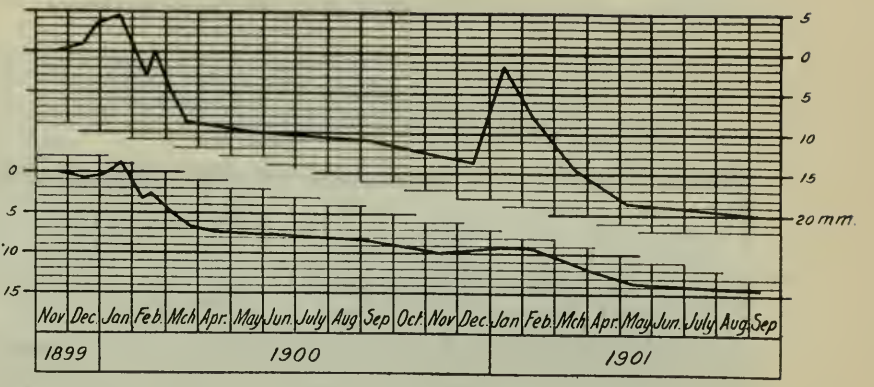
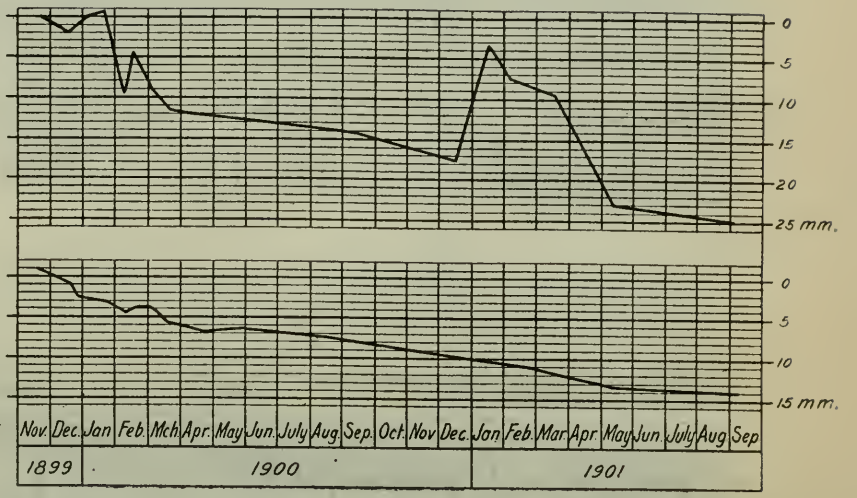


Fig. 6a
Point 17.

Fig. 6b
Points 1-25.


0 5 10 15 20 25 mm.
0 5 10 15 mm.
Nov Dec Jan Feb Mch Apr May Jun July Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun July Aug Sep
1899
1900
1901

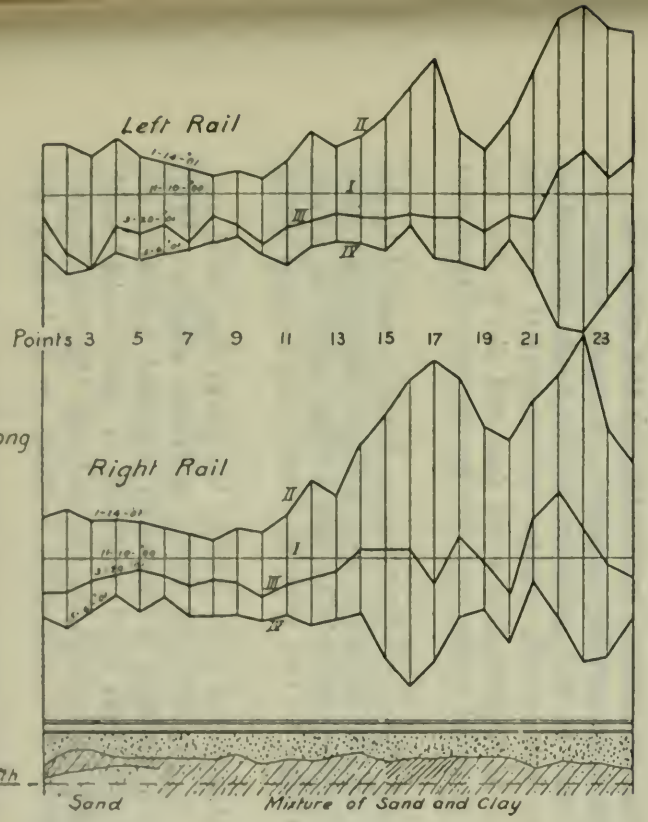


Fig. 7.
Rails 9 meters long on longitudinal stringers.

Explanations:

Gravel
Sand
Clay
Clay bearing Sand
Broken Stone
Rail Impact.
Center line of Ties
Frost Depth

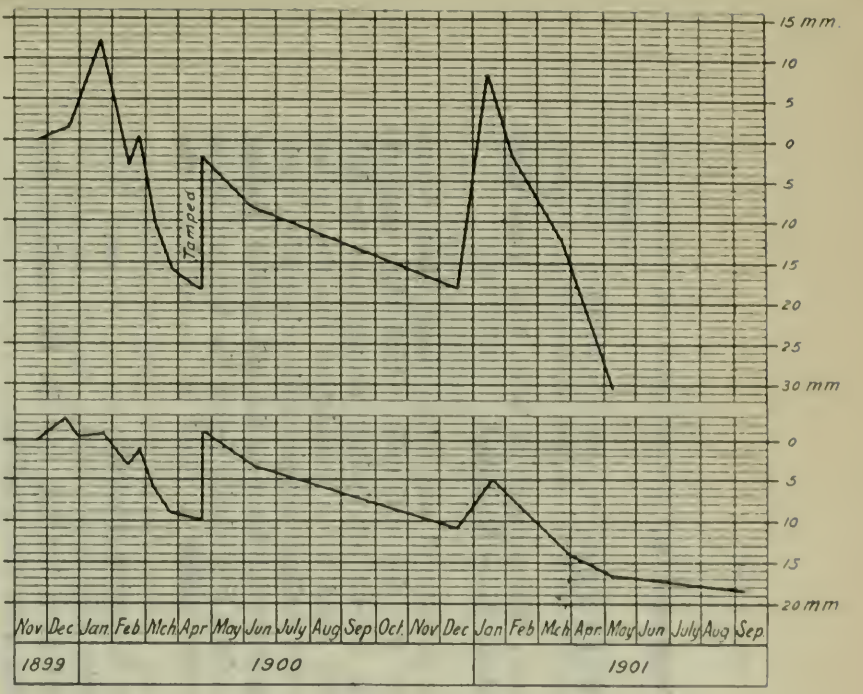
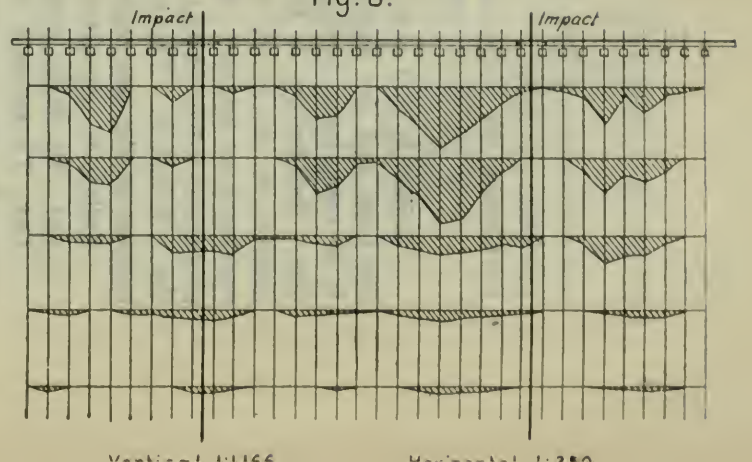


Fig. 7ª
Point 23

Fig. 7ᵇ
Points 1–13.

Equalisation of the hollows under the Ties due to passing Traffic.
Fig. 8.



Appendix D.

BALLAST.

By GEORGE W. VAUGHAN, Engineer Maintenance of Way, New York Central & Hudson River Railroad.

Ballast is that portion of the permanent way of a railway which forms the firm and dry foundation for the ties and rails, which they support. It is sometimes distinguished as sub-ballast, ballast proper, and top-ballast. Sub-ballast is that portion used as a foundation for the ballast proper, or as a mat between the ballast proper and sub-grade, made necessary on account of the poor material forming the sub-grade. Ballast proper, or under-ballast, is that which lies wholly below the ties and above the sub-ballast. Top-ballast is that which is filled in around from the bottom to the top of the ties.

Ballast is necessary for the following reasons:

(a) To drain water from the ties.

(b) To provide a firm and even bearing for the ties and to distribute the pressure from the ties over the roadbed.

(c) To provide drainage, so as to avoid heaving by frost.

(d) To supply filling material between the ties and to hold them in place.

(e) To prevent the growth of grass and weeds in the track.

(f) To allow surfacing and raising of track without disturbing the roadbed.

Ballast is a most important item and upon its quality depends the condition of the track, also the economy in maintenance and operation.

Ballast material should be carefully selected. A dusty ballast will cause greatly increased wear on the equipment and on roads with extensive passenger traffic an innumerable number of complaints from the traveling public, and it is as important to avoid dust and dirt by the use of clean ballast as it is to avoid smoke and dirt by the use of hard coal for fuel.

The best ballast is that which will best form a durable support to the ties, will not change its consistency when wet, will not disintegrate upon exposure to the elements, retains its solidity and position under the effects of traffic, gives good drainage, be free from dust and make an easy-riding track.

Broken stone and furnace slag drain readily, but burnt clay, sand, etc., will retain water more or less and will heave in frosty weather. With earth or mud ballast good drainage is absolutely essential to enable the track to be kept in safe and fairly good condition, as water-soaked earth becomes pasty and squashes up between the ties and over the right-of-way, and when in such condition it is impossible to tamp, so as to keep the track in surface.

A good depth of ballast will cheapen the maintenance by keeping the

beds of the ties well drained, and it is not economy to economize too much on ballast.

The depth of ballast varies on different lines and according to the practice of different engineers, the following may be taken as ordinary limits:

Sub-ballast	10 in. to 18 in.
Lower-ballast	9 in. to 18 in.
Upper-ballast	6 in. to 8 in.
Totals	25 in. to 44 in.

The materials most generally used are Broken Stone, Furnace Slag, Gravel, Burnt Clay, Sand, Cinders and Earth.

DEFINITIONS.

Broken or Crushed Stone.—Stone broken by mechanical means into small fragments of specified size.

Gravel.—Small worn fragments of rock, coarser than sand, from natural deposits.

Sand.—Any hard granular rock material, finer than gravel or coarser than dust.

Cinders.—The ashes or residue from coal used in locomotives and other furnaces, including the sparks from the front end of locomotives.

Slag.—Waste product. A more or less vitrified form of furnace reduction of ore. This to include the granulated slag formed by dumping hot slag into water or any other product of a blast furnace, iron, copper or lead.

Burnt Clay.—Clay or gumbo, which has been treated with fire.

Mud Ballast.—Any natural material used as ballast, if, when well drained, will not churn under the ties.

DESCRIPTION.

Broken Stone.—This in general is considered the best material for ballast, as it meets the requirements; does not freeze nor heave in cold weather, and can be worked in wet and dry weather alike. Almost any hard building stone may be used, provided it breaks with an angular fracture and not into thin, flat pieces. Granite, trap, limestone and flint are mostly used.

Gravel.—This material is more used than any other and is a varying quality. It may be sandy, dusty or loamy, or else full of large stone, which, unless removed, will make an irregular and rough riding track. The best gravel should be clean and coarse, and as far as possible of uniform size and quality. It does not give as good drainage as stone, but a fairly coarse and clean gravel generally proves satisfactory, provided plenty of it is used.

Sand.—This, when clean, sharp and granulated, makes fairly good ballast under light traffic, but unless it is very coarse requires constant atten-

tion and renewal, involving a great deal of maintenance work, as it runs out from under the ties and is gradually weathered away by the action of the elements. Where gravel or sand ballast is full of dust it should be provided by a top dressing of coarse cinders or coarse stone screenings, so as to avoid dusty track.

Slag.—Furnace slag or cinder is commonly used on roads in the vicinity of blast furnaces and iron works. Coarse slag is about as durable as broken stone and in some ways almost as good, except that the ties decay more rapidly from dry rot than in stone ballast. At the present time slag from blast furnaces and iron works is being furnished in granulated shape. This is done by dumping the slag into water, the product of which, when taken out, is similar to and about the same quality as sand ballast. When first placed in the track it is very dusty, but the repeated rains relieve this condition. Its drainage qualities are much better than that furnished by sand ballast.

Burnt Clay.—This is being used in England and other foreign countries; has extended to this country and is being used extensively in the West. The most suitable is brick clay, or almost any clay that has not too much sand, gumbo or clayey earth. Burnt clay is very light and is about equal to screened locomotive cinders.

Mud Ballast.—Dirt, earth and mud are used, the ballast being composed of natural soil along the road. This is the cheapest material to be used and generally the most troublesome to maintain. It is of a variable quality, from sandy to clayey. Unless very sandy, cakes in hot weather and when any work is done it becomes intolerably dusty. In the winter it heaves badly by frost and in rainy weather it washes out and in continued wet seasons, or in the spring, when the frost is coming out of the ground, it becomes so soft that it is almost impossible to keep track in safe condition, as the ties churn the saturated roadbed into mud. In other words, good mud ballast is a continuous performance, every day in the year, Sundays included.

SPECIFICATIONS.

BROKEN STONE.

Broken stone ballast shall be made from stone hard enough to prevent pulverizing under the treatment to which it is subjected, also durable and tough enough to resist the disintegrating action of the elements where it is used, or from other stone, acceptable to the Engineer.

When crushed it shall break into angular pieces and the maximum size shall not exceed pieces which will pass through a revolving screen having two (2) in. holes, and the minimum size shall lie on a revolving screen having three-quarter (¾) in. holes.

Stone shall be crushed in suitable crushers; be clean and free from all dust, rubbish, dirt and particles three-quarter (¾) in. in diameter and under. If crushed by hand, the stone should be broken in clean places especially selected for the purpose.

STONE SCREENINGS.

Stone screenings shall be made from the same quality of stone as stone ballast, as it is a by-product of the crusher. The maximum size shall not exceed pieces which will pass through a revolving screen having three-quarter (¾) in. holes and the minimum size shall lie on a revolving screen having one-quarter (¼) in. holes. The product shall be free from all dust, dirt, rubbish and particles that will pass through a one-quarter (¼) in. ring and under.

CINDERS.

Cinder ballast shall be free from ashes, dirt and rubbish.

SLAG.

Slag ballast shall be free from lime, dirt and rubbish, and the product from the mill, if not quenched in water, should be broken into pieces which will pass through a revolving screen having two (2) in. holes, and the minimum size shall lie on a revolving screen having three-quarter (¾) in. holes. If slag is quenched in water to form granulated slag, this product shall be free from dirt, lime and rubbish, or any material that will not pass through a two (2) in. ring.

GRAVEL.

The best should be clean and coarse, free from dirt, dust, marl lime, and stone that will disintegrate under the action of the elements, and should range in size from two (2) in. in diameter to coarse sand. Gravel should be screened or washed where prevention of dust is an object, but this need not be done when the traffic is such that it is not objectionable.

SAND.

Fine gravel or sand ballast should be free from dirt, rubbish, marl lime and pebbles that will disintegrate under the action of the elements, and should range in size from two (2) in. in diameter to fine sand, a portion of about 75 and 80 per cent. to 20 and 25 per cent. of coarser material.

BURNT CLAY.

This ballast should be made of clay free from sand or silt. The clay should be burnt hard and thoroughly. The fuel used should be fresh and clean enough to burn with a clean fire. Ballast should be allowed to cool before loading. Absorption of water should not exceed fifteen (15) per cent. by weight. Ballast must be free from all worthless material, dirt, dust and rubbish.

EARTH OR MUD BALLAST.

Ballast should be taken from sub-soil and be of such material that when placed in the track water will drain off readily from the top.

TOP-BALLAST.

This should consist of the same material as ballast proper, except when a dustless roadbed is required the upper two or three (2 or 3) in.

should consist of two or three-quarter (2 or ¾) in. stone, slag, screened gravel or cinders.

SUB-BALLAST.

This should be sand, stone screenings, stone dust, granulated slag, or any material that will form a cushion and drain readily. Sub-ballast should be clean and free from dirt and rubbish.

RECOMMENDED PRACTICE.

STONE, SLAG AND GRAVEL.

Coarse stone, coarse slag or coarse gravel should be used, if obtainable, on all high speed and heavy freight tracks. When not obtainable, the best available material should be used, and if a dustless track is desired top dress with crushed stone, screenings, crushed slag, washed gravel or cinders.

CINDERS, STONE SCREENINGS AND SAND.

The use of cinders, stone screenings and sand as ballast is recommended for the following situations on Main and Branch Lines with light traffic:

On sidings and in yard tracks; as sub-ballast in wet springy places, in cuts, on fills, and through clay bottoms; as sub-ballast on new work where fills are settling and at places where track heaves from frost.

BURNT CLAY.

The use of burnt clay as a ballast is recommended for the following situations:

On Main and Branch Lines with medium traffic. On sidings as a top dressing to secure a dustless track.

EARTH AND MUD.

The use of earth or mud is recommended only when more suitable material is not obtainable. If used it should be rounded up in the center of the track, so that water will drain off readily.

RECOMMENDED DEPTH OF BALLAST.

Kind of Ballast.	Sub-Ballast.	Ballast-Proper.	Top-Ballast.
Crushed stone		12 in. to 18 in.	6 in. to 8 in.
Crushed stone screenings	10 in.	10 in. to 12 in.	6 in. to 8 in.
Crushed slag		12 in. to 18 in.	6 in. to 8 in.
Granulated slag	12 in.	10 in. to 12 in.	6 in. to 8 in.
Gravel	10 in.	12 in. to 18 in.	6 in. to 8 in.
Sand	12 in.	10 in. to 12 in.	6 in. to 8 in.
Cinders	12 in.	10 in. to 12 in.	6 in. to 8 in.
Burnt Clay		12 in. to 18 in.	6 in. to 8 in.
Earth or Mud			9 in. to 11 in.
Dust Guard: All kinds of ballast			2 in. to 3 in.

RECOMMENDATIONS AS TO THE USE OF OIL TO SECURE A DUSTLESS ROADBED.

Approximately 2,000 gallons of oil are required for each mile of single track and the first cost is about $80.00 per mile. Oil is usually applied in June and the one application is sufficient for the year, except where roadbed is disturbed, when a local application is necessary, which can be made with a sprinkling pot. The application of subsequent years is thinner and is sometimes postponed until dust develops, when the cost of applying, per mile of single track, where the company owns its own oil car, exclusive of the royalty, is approximately $38.00.

The oil is generally furnished by the Standard Oil Company for this purpose and appears to be unrefined, from which the more volatile parts have been removed.

The ballast on which oil is generally used is either cinder, a mixture of sand and gravel or sand. The oil has no appreciable effect on the effort to keep good line and surface, except where the ballast is largely sand. The oil makes the sand incohesive, causing the line and surface to deterioate very rapidly. The oil helps to shed rainwater, but has no apparent effect on the durability of ballast, except as stated above, in regard to sand ballast. The oil penetrates usually about one (1) in. on cinder. On sand it appears to soak down indefinitely.

If clean washed gravel can be obtained or if gravel is only dusty a short time after being disturbed, the use of oil is not recommended, as even after the oil is applied, the high-speed trains raise a fine oily dust which is worse than the clean dust, so that if a dustless roadbed is required, the recommendations are the use of a top dressing of coarse stone screenings, crushed slag, burnt clay, screened or washed gravel or screened cinders.

DESCRIPTION OF BALLAST AS SHOWN BY PHOTOGRAPHS ACCOMPANYING THIS REPORT.

No. 1. "Trap Rock" from Westfield, Mass.

No. 2. "Limestone" from Clinton Point, N. Y.

No. 3. "Gneiss," "Granite," "Hornblende" and other refuse from an iron mine at Tilly Foster, N. Y.

No. 4. "Limestone" from South Bethlehem, N. Y.

No. 5. "Marble" from Gouverneur, N. Y. Note the difference in color. Light portion is direct from the crusher, while the dark portion has been in track two years.

No. 6. "Flint" and "Limestone" from Akron, N. Y.

No. 7. "Burnt Clay."

No. 8. "Furnace Slag."

No. 9. "Trap Rock" from Little Falls, N. Y.

No. 11. "Sandstone" from Medina.

No. 12. "Limestone" from Pennsylvania.

No. 13. "Limestone" from Bellefonte, Pa.

No. 14. "Screenings" from Akron, N. Y.

No. 15. "Crystalized Sandstone" from Niagara Falls.

No. 16. "Gravel" from Beaver River. This is such gravel as is used on the Adirondack Division of the New York Central.

No. 17. "Gravel" from Yosts on the Mohawk Division of the New York Central and is of first quality.

No. 18. "Gravel" from Todd's Pit on the M. & M.

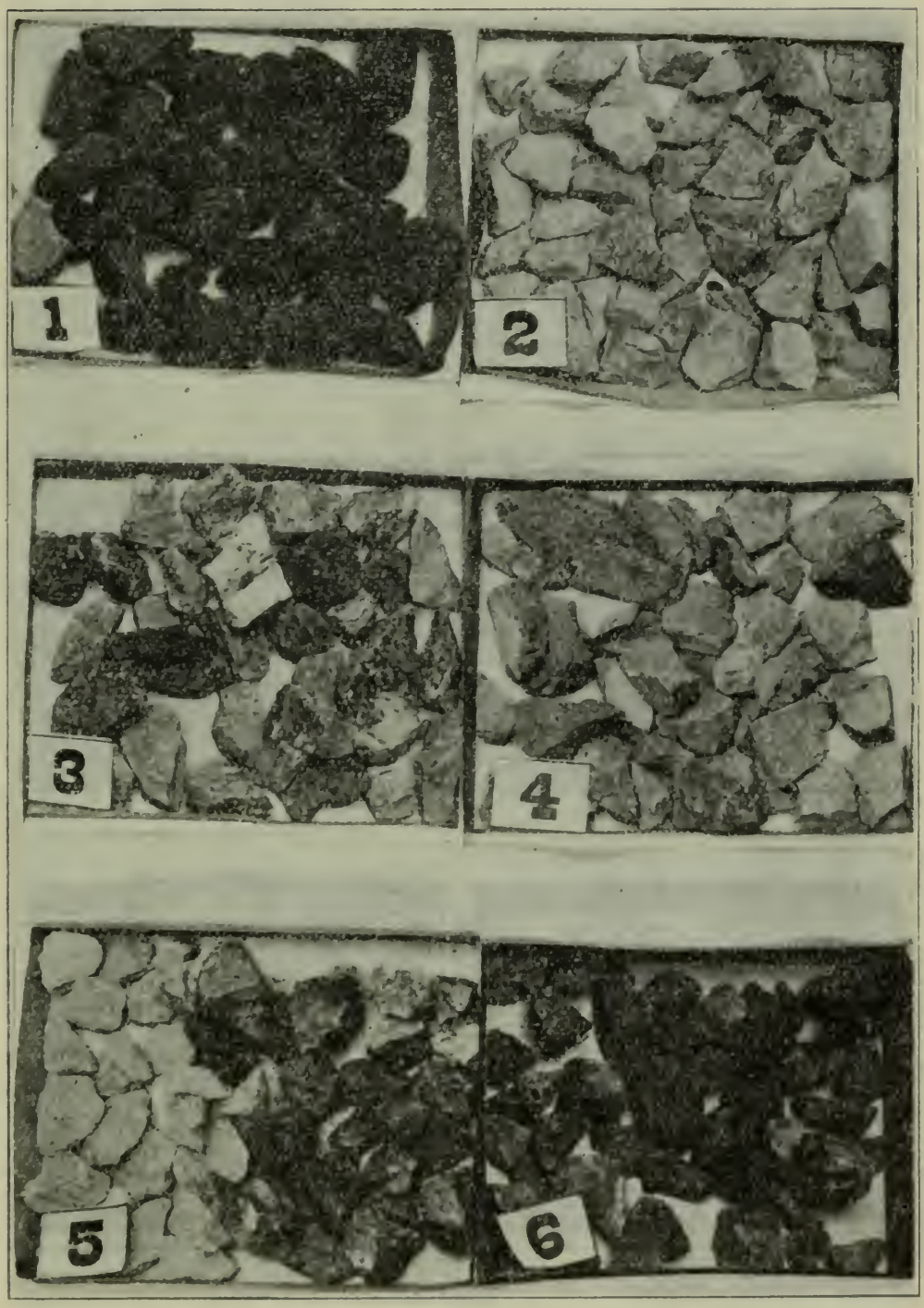
No. 19. "Gravel" from Glenfield Pit on the R. W. & O. Division. This material is coarse sand and makes very good ballast, though somewhat dusty when put in track.

No. 20. "Granulated Slag" from blast furnace. Sample here shown is quite coarse and full of black cinders.

No. 21. "Gravel" from Fisher's Pit, Western Division.

No. 22. "Medium Coarse Gravel" from Fisher's Pit, Western Division.

No. 23. "Locomotive Cinder."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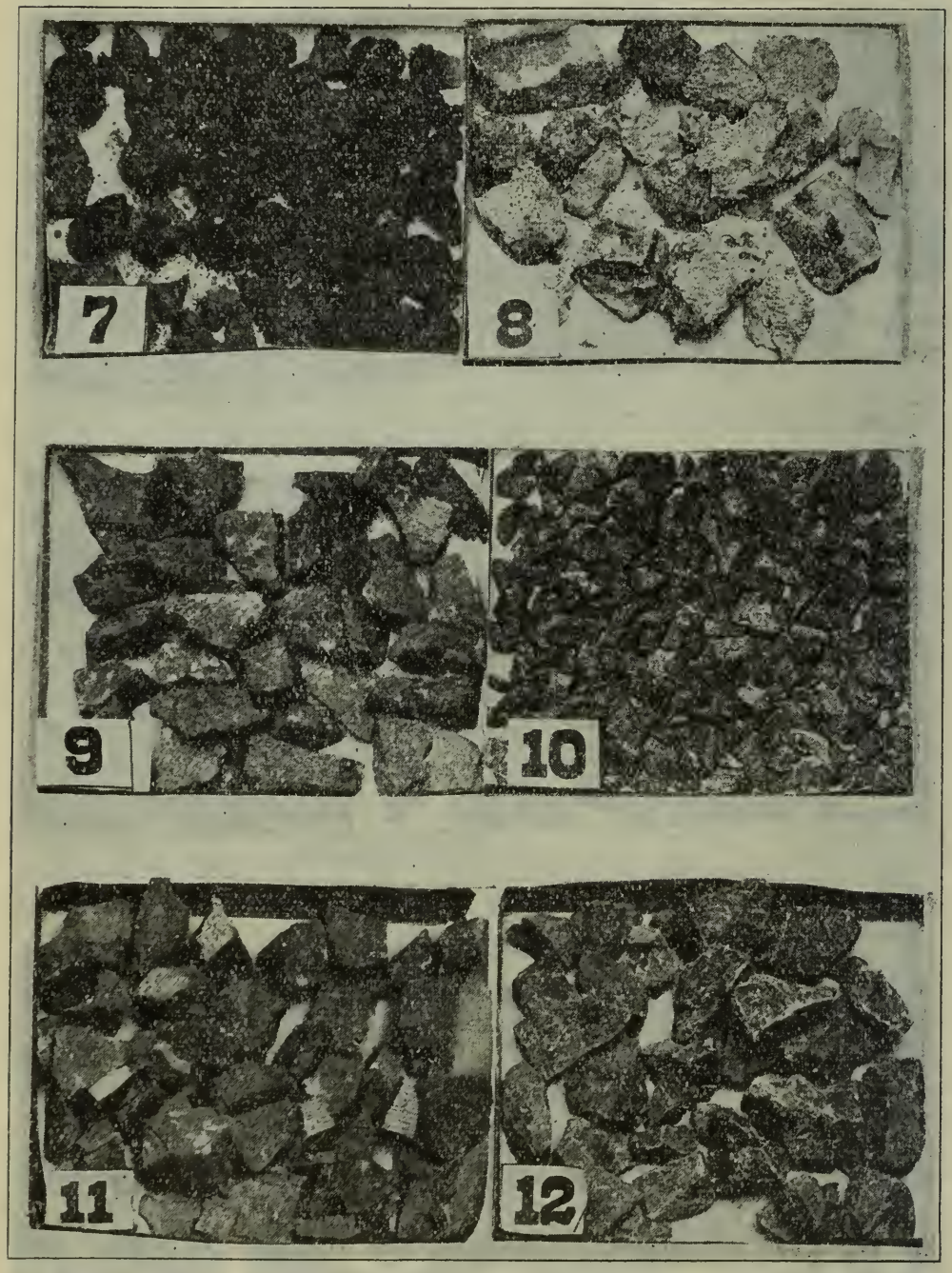
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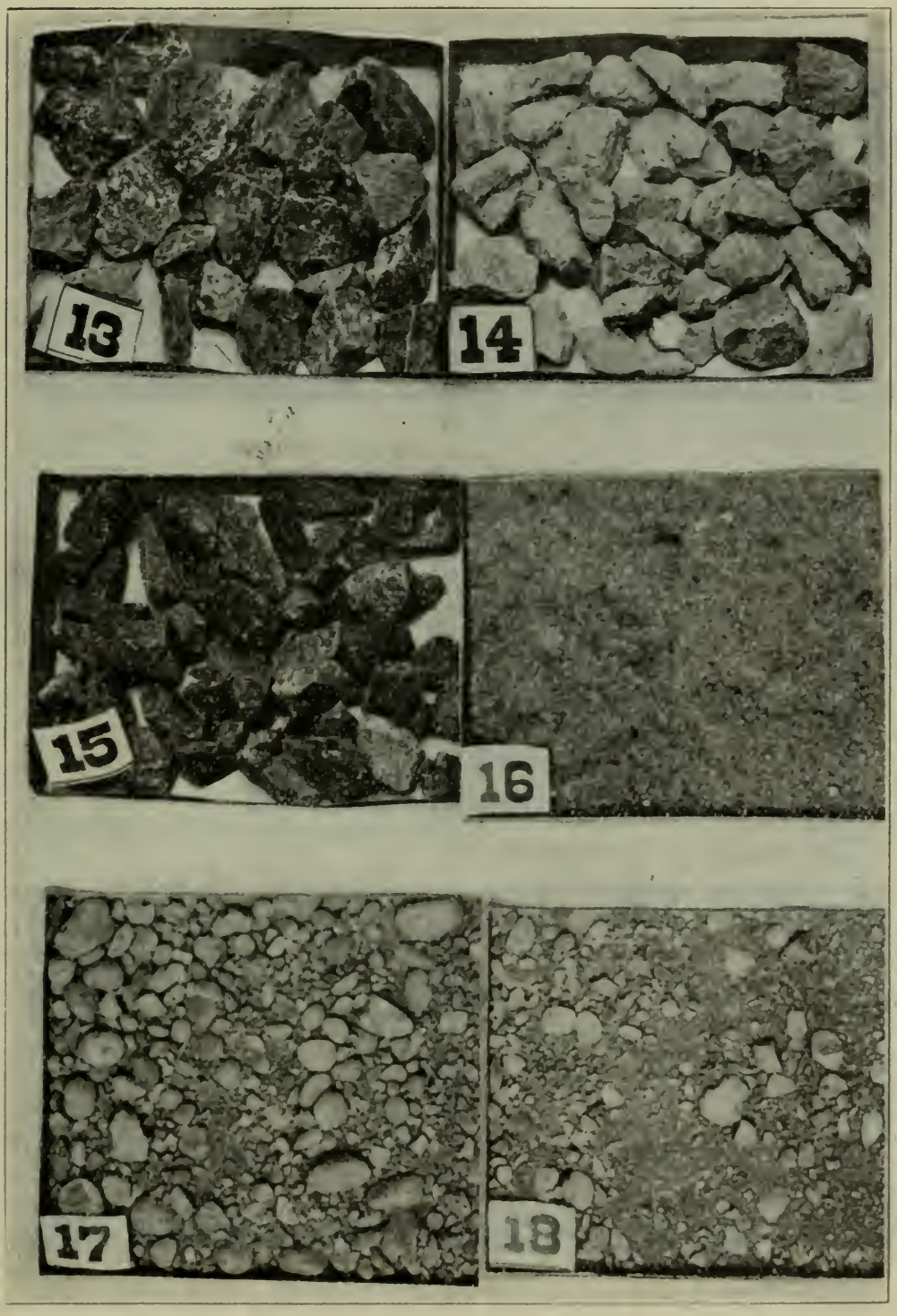
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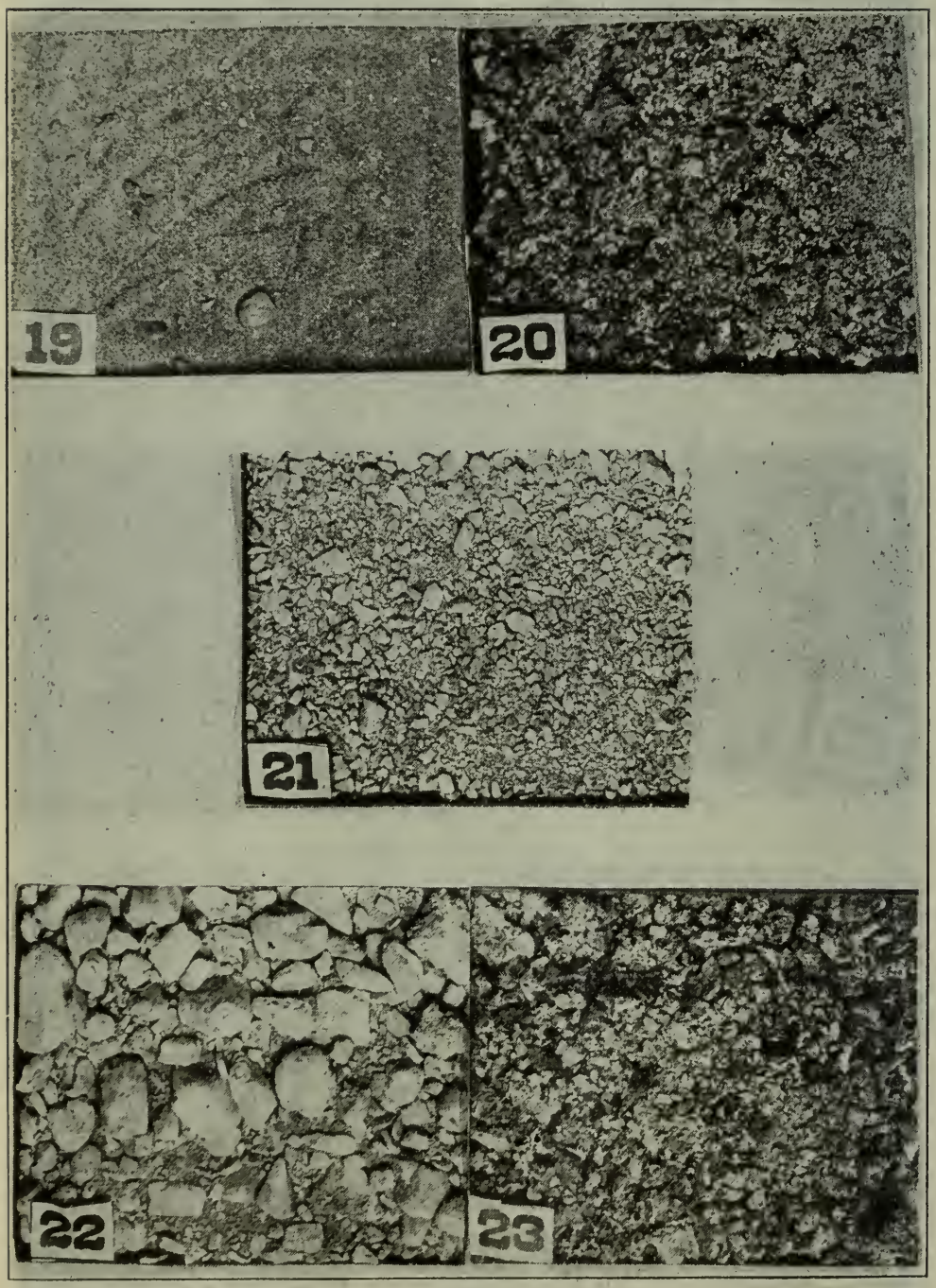
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REPORT OF COMMITTEE III—ON TIES.

L. A. Downs, *Chairman;*
H. W. Brown.
W. J. Burton.
L. C. Hartley.
E. D. Jackson.
F. G. Jonah.
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G. W. Merrell, *Vice-Chairman;*
Duncan MacPherson.
L. M. Perkins.
J. G. Shillinger.
G. D. Swingly.
D. W. Thrower.
H. K. Wicksteed.
H. S. Wilgus.
Committee.

To the Members of the American Railway Engineering Association:

Your Committee on Ties has had under investigation during the past year three of the subjects assigned by the Board of Direction, and herewith respectfully submits its report:

(1) SIZE OF CROSS-TIES REQUIRED FOR THE STRESSES TO WHICH THEY ARE SUBJECTED.

The stresses to which ties are subjected cannot be considered as having no interrelation to the other parts of a roadway. On the contrary, the size of rail, the load above and the bearing beneath the tie, the subsoil, the character of the material between ties, the presence or absence of tie-plates, screw versus common spikes, and many other conditions, actual and theoretical, must be considered. It was thought best to obtain from various members opinions along certain lines and for that purpose a set of questions was prepared (see Exhibit A) by the Sub-Chairman and sent out by the Secretary to all members. Forty replies, representing about 4 per cent. of membership, or 32 per cent. of the mileage represented in the Association, were received. These replies have been tabulated (see Exhibit F and F-1). The preparation of the questions and the tabulation of the answers have required considerable time and patience. The tabulation is worthy of careful study, for it contains information and data of much value. Indeed, it is an epitome of much that is not germane to but which is closely allied to the topic. The size of Table F is regrettable, but it is considered that the information in that form is most readily comparable.

The various sizes of ties already in common use, as prepared by the

Tie Committee, are tabulated on pp. 771-774, Proceedings for 1905, American Railway Engineering Association. This table has been rearranged in order to tabulate information under the following heads, viz.:

(1) Different number of ties per 30-ft. rail. (See Exhibit B.)

(2) Is a 6x8x8 tie too small; is a larger tie than 6x8x8 undesirable? (See Exhibit C.)

(3) Different sizes of cross-ties in current use. (See Exhibit D.)

A study of Exhibit B shows a preponderance of mileage and membership (42.7 and 38 per cent., respectively) in favor of 16 ties to the 30-ft. rail (2,816 per mile), main track. During the six years intervening the railroads seem to have increased the number, for the general average of a rail-bearing area, as per Exhibit F, is about 40 per cent., whereas in 1905 it ran about 35½ per cent. Exhibit B, however, indicates that in 1905 17 (2,992 per mile) and 18 (3,168 per mile) ties per 30-ft. rail (bearing area of 38 per cent. and 40 per cent., respectively, based on 8-in. ties) were in strong favor.

Exhibit C was prepared in order to ascertain the feeling as to proper size of cross-ties. It would appear that 59 per cent. of the mileage voting believed a 6x8x8 ft. too small, whereas 96 per cent. thought a larger tie not undesirable.

Exhibit D indicates 22 sizes of cross-ties in current use, with 47 per cent. of the mileage and 48 per cent. of the membership reported as using 6x8x8, whereas that tie is believed unsatisfactory by 59 per cent. (Exhibit C) of the voting mileage, and 96 per cent., Exhibit C, believe a larger tie desirable. These tables all show an inconsistency among the railroads as to what they really do desire. There is no doubt that the sentiment is in favor of a larger tie, but the sentiment stage is not overcome.

The length of tie apparently has not been considered so much as width and depth. Exhibit D shows that of 139,029 miles represented, 25,112 miles or 18 per cent. reported ties 8 ft. 6 in. in length. The length of a tie between recognized limits has a great influence on the distribution of its superimposed load over the ballast and consequent tie crushing as well as the amount of maintenance work required with poor ballast, poor subgrade, or both. Ten and three-tenths (10.3) per cent. reported in favor of a 7x9x8 ft. 6 in. and none in favor of a 6x8x8 ft. 6 in. (6x8x8 ft. is the most popular).

A. M. Wellington, in his incomparable treatise on "The Economic Theory of Railway Location," touches admirably on the topic of this Committee in paragraphs 1044 to 1050, inclusive. The extracts from these paragraphs as follows are most apropos:

"1044. The number of these (ties) cannot be too great for economy, until they become so close as to impede tamping, which is when about 40 per cent. of the length of the rail rests upon ties.

"1046. . . . . In endeavoring to get the utmost stability at the least cost the first essential is to use ties as freely as is possible, and the next essential is to decide between a heavier rail and more tamping to supply the deficit.

"1051. . . . . The best dimensions for a tie are about 7 in. thick, 8 ft. 6 in. long and 7 in. to 9 in. face."

The Committee has been unable to find any data in the publications of the Association bearing on the crushing strength across the grain of the various woods used for tie purposes, except on pp. 853-4, Volume 11, Part 2, Proceedings, 1910, American Railway Engineering Association. That table is intended partially to show the effect of preservative treatment on crushing strength at elastic limit and the average of tests for various woods is as follows:

Table I.

BEARING STRENGTH OF TIES UNDER THE RAIL TESTS.

(See Proceedings, Vol. 11, Part 2, pp. 853-4.)

	Natural		Treated		Remarks
	No. of Tests	Crushing at E. L.	No. of Tests	Crushing at E. L.	
Red Oak	100	1090	100	1080	.....
Loblolly Pine	70	612	70	591	1. Crude oil, 529.
Shortleaf Pine	30	640	30	618	1. Crude oil, 373.
Longleaf Pine	20	688	20	725	.....
Red Gum	29	830	29	791	1. Crude oil, 655.
	249		249		

The natural crushing strength at elastic limit herein given does not compare favorably with simlar results obtained by the United States Government (see Exhibit G), because of the difference in character of material and moisture content. The Forestry Service Circular 189 (see footnote page 311 states, " . . . it is not safe to base working stresses on results secured from any but green material."

The Director of the Forest Products Laboratory, Forestry Service, Madison, Wis., furnished the Sub-Committee blueprints of crushing strength at elastic limit of timber—air dry and green and from which prints Exhibit G is extracted. This table well illustrates why green timber for ties should be shunned.

Exhibit E is a list of articles on the relation of the size of cross-ties to the stresses to which they are subjected, from search made at the Library of the American Society of Civil Engineers, June 12, 1911.

This list is supplemented as follows:

(1) "Discussion of Committee Report on Ballasting," by W. C. Cushing; Bulletin 76, June, 1906, American Railway Engineering Association.

(2) "A Study of Stresses Existing in Track Superstructure and Rational Design Based Thereon," by O. E. Selby; Bulletin 80, October, 1906, American Railway Engineering Association.

(3) "Stresses in Track Fastenings," by W. C. Cushing; Bulletin 104, October, 1908.

(4) 1. "Experiment to Determine the Necessary Depth of Stone Ballast," being a report of General Manager's Committee, Pennsylvania Railroad. 2. "Gravel as Ballast," by C. Bräuning. (Translated from the German.) Bulletin 136, June, 1911.

(5) Volume 7, Proceedings, 1906 (out of print), American Railway Engineering Association.

(6) Wellington, A. M., paragraphs 1044 to 1050.

(7) International Railway Congress, Proceedings, 1910, Volume 1, Question 2, Report No. 1. Strengthening of Track, by J. W. Jacomb-Hood, Engineer London & Southwestern Railway.

Bulletin 136, June, 1911, contains an article entitled "Experiment to Determine the Necessary Depth of Stone Ballast," being a report of the General Manager's Committee of the Pennsylvania Railroad. This report is based on spacing of white oak ties 16½ in. face to face for a 7x9x8 ft. 6 in. tie, which tie spacing is equivalent to 25½ in. center to center, or 14 ties per 30 ft. rail, which is equivalent to 35 per cent. bearing. That Committee recommended (page 17) "the use of 24 in. of stone ballast underneath the ties to meet satisfactorily the conditions that exist to-day and which will become probably more severe as time goes on, and in addition to the 24 in. of trap rock ballast beneath the ties, there should be provided a layer of engine cinders, gravel or an equivalent to act as an absorbent mat to promptly and properly dispose of the water falling on the track in such a manner as to prevent its softening the roadbed material."

Your Committee is of the opinion that further investigation should be made upon these lines to ascertain relation of tie spacing to different depths of ballast.

O. E. Selby, in Bulletin 80, October, 1906, American Railway Engineering Association, treats of the stresses in ties. His recommendation is 12 in. stone ballast directly under tie, superimposed on 12 in. gravel, with ties spaced 20 in. center to center (45 per cent.).

Thos. H. Johnson's formulæ for depth of ballast and tie-spacing for gravel and stone ballast appear in Bulletin 76, June, 1906.

It came to the notice of the Sub-Committee that the Erie Division of the Pennsylvania Railroad was experiencing trouble with yellow pine tie splitting; it therefore wrote to R. L. Roe, Division Engineer, and replies from his Supervisors, W. E. Brown, J. S. Considine, W. S. Wilson, are given, as follows:

"In reply to your circular of the 10th inst., concerning effect of heavy engines on yellow pine ties, would advise that, on that part of the Maryland Division between Baltimore and Perryville, where no engines heavier than D16d were used, yellow pine ties were found equal to oak as far as the wearing qualities were concerned under the 100-lb. rail without tie-plates. This was prior to 1905.

"When I came to this division in July, 1905, I found that a fair percentage of yellow pine ties were used in the main track, some of which had been in service about three years and were all in fair condition. At that time only one class E engine was in service. During the next two years more of this heavier class of engines were used, and in the spring of 1907 we noticed that some of the yellow pine ties which had been in service less than a year were beginning to show signs of crushing. With the increased use of the class E engines the tendency to split seems to grow more pronounced yearly.

"The R. & C. (a light traffic line) has a large percentage of yellow pine ties in track, but fail to notice so marked a tendency in the pine ties to split as on the Renovo Division, in spite of the fact that very few of the branch ties are tie-plated.

"Perhaps this difference may be due to the increased tonnage on the Renovo Division, but the fact that tie-plates are more generally used between West Creek and Strebor should counteract to some extent the heavier traffic and we are inclined to attribute the failure of the yellow pine ties more to excessive axle load on class E engine drivers than to the number of axles which may be hauled over the division."

"Replying to yours of the 10th, regarding effect of heavy engines on pine ties, we find that pine ties without tie-plates become crushed and checked badly under the rail long before they are decayed or otherwise unfitted for service.

"The application of a tie-plate when tie is in this condition will, of course, prolong the life to some extent.

"It is the practice at the present time to use plates on all pine ties when first put in track, and while the greatest amount of service is obtained from the tie by this method, our experience has not been sufficient in this line to say definitely that they will not crush under the heavy concentrated wheel loads where plates are so applied."

"In reply to Mr. H. S. Wilgus' letter of the 8th inst., relative to crushing our yellow pine ties due to the heavy concentrated wheel loads of our heavy engines, it has always been my opinion that if we get good sound yellow pine ties and use tie-plates with them, we will get practically the same life out of them as we get out of the white oak ties.

"Some years ago when track elevation work was done on the P. B. & W. through Chester and Wilmington, one of the main tracks was laid in white oak ties and the other in yellow pine ties. I have been told that a great many of these pine ties are still in track, while a majority of the oak ties have been removed. Pine ties without tie-plates soon split and crush and wear out rather than rot out. We have, however, a great many now in track on this division that were installed about eleven years ago with tie-plates and they are in fair condition considering the service they are giving."

EXHIBIT A.

COPY OF CIRCULAR.

(1) What percentage of a rail length should have a bearing on the ties? Does the per cent. mean per cent. of linear distance or bearing area?

(2) Has this percentage any relation to, (a) Kind of timber used for ties? (b) Kind of ballast? (c) Character of sub-grade? (d) Tangent vs. curve? (e) Minimum distance between face of ties?

(3) If the percentage is capable of mathematical deduction, please give the method, etc.

(4) Is crushing hastened by natural checking of ties?

(5) Which class of wood checks most?

(6) Does preservative treatment tend to increase the tendency to check?

(7) Does preservative treatment affect the natural crushing unit stresses?

(8) (a) With the increased tie consumption and the decreased available tie supply, can the demand for larger sectional area of ties be met? (b) If a larger sectional area of the tie is not available, what would you recommend as next best thing to do—use steel or composite or what not?

(9) Has the application of screw or square spikes any effect on crushing?

(10) Relation of kinds of ballast to tie crushing?

(11) Relation of character of sub-grade to tie crushing?

(12) Relation of axle load to tie crushing.

(13) Relation of frequency of maximum axle load as applied to a tie to tie crushing?

(14) Relation of maximum axle load to weight of rail and consequent tie crushing?

(15) Relation of impact at joints to tie crushing?

(16) Relation of size of tie-plates to crushing of ties?

EXHIBIT B.

DIFFERENT NUMBER OF TIES PER 30-FT. RAIL AND NUMBER OF MILES OF TRACK REPRESENTED UNDER EACH SUCH NUMBER.

Based on Table published on pp. 771-774, Vol. 6, Proceedings, 1905, American Railway Engineering Association.

No. of Ties to 30-ft. Rail, M. T.	Number of Miles	Percentage of Total Mileage Voting	Roads Voting	
			Number	Per cent of those Voting
15	1,834	1.4	12	9.4
16	55,380	42.7	48	38.0
17	17,805	13.8	21	16.7
18	24,190	18.7	21	16.7
19	4,589	3.5	3	2.4
20	3,249	2.5	3	2.4
14–16	7,180	5.5	2	1.6
15–16	83	—	1	0.8
15–17	154	0.1	1	0.8
15–18	5,984	4.5	1	0.8
15–19	1,416	1.0	1	0.8
16–17	110	0.1	1	0.8
16–18	3,565	2.7	3	2.4
16–19	161	0.1	1	0.8
17–18	3,016	3.0	3	2.4
17–20	153	0.1	1	0.8
18–19	49	0.0	1	0.8
18–21	404	0.3	2	1.6
	129,322	100.0	126	100.0
Total in Membership.....	259,384	....	990	....
Per cent of Total....	50	....	13	....

EXHIBIT C.

IS A 6 x 8 x 8 FT. TIE TOO SMALL? IS A LARGER TIE THAN 6 x 8 x 8 FT. UNDESIRABLE?

Based on Table published on page 771, Vol. 6, Proceedings, 1905, American Railway Engineering Association.

	Yes		No		Total Miles appearing in table	Total voting on this point	
	Miles	Per cent of Total	Miles	Per cent		Miles	Per cent
Is 6x8x8 ft. too small.....	33,936	59	23,678	41	129,322	59,614	45
Is a larger tie than 6x8x8 ft. undesirable	2,220	4	51,755	96	129,322	51,755	40

EXHIBIT D.

DIFFERENT SIZES OF CROSS-TIES IN CURRENT USE.

Based on Table published on page 771, Vol. 6, Proceedings, 1906, American Railway Engineering Association.

Size of Ties	Miles of Road Using Same		Roads Voting	
	Miles	Per cent	Number	Per cent
6 x 7 x 8.....	222	0.2	2	1.4
6 x 8 x 8.....	65,432	47.3	67	48.0
6 x 9 x 8.....	830	0.6	4	2.8
7 x 7 x 8.....	191	0.1	1	0.7
7 x 7 x 8'6".....	6,506	4.7	6	4.2
7 x 8 x 8.....	13,999	10.1	16	11.2
7 x 8 x 8'6".....	2,498	1.8	2	1.4
7 x 9 x 8.....	5,184	3.7	6	4.3
7 x 9 x 8'6".....	14,448	10.3	13	9.2
7 x 9 x 9.....	8,100	5.8	10	7.0
6 x8-10x 8.....	4,182	3.0	1	0.7
6-7 x6-12x 8.....	1,857	1.4	2	1.4
6½—8x7-11x 8.....	336	0.2	1	0.7
7 x 7-9x 8.....	5,459	3.9	2	1.4
7 x9-10x 8.....	1,440	1.0	1	0.7
8 x 9 x 8'6".....	952	0.7	1	0.7
7 x 10 x 8.....	1,869	1.3	1	0.7
7 x 10 x 8'6".....	708	0.5	1	0.7
8 x 8 x 8.....	3,024	2.2	1	0.7
7 x7-12x 8.....	163	0.1	1	0.7
7 x7-10x 8.....	161	0.1	1	0.7
7 x7-14x8'6"	1,468	1.0	1	0.7
	139,029	100.0	141	100.0

EXHIBIT E.

BIBLIOGRAPHY ON SIZE OF CROSS-TIES IN RELATION TO THE STRESSES TO WHICH THEY ARE SUBJECTED.

LIBRARY OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

Note: This is not a complete search.

"Loadings for Railroad Bridges," Informal Discussion. Transactions, American Society of Civil Engineers, v. 51, p. 106. (Contains a

brief reference as to the advisability of increasing the size of ties for heavier railroad traffic.)

"Metal and Reinforced Concrete Ties." (Editorial.) Railroad Age Gazette, v. 44, p. 593 (May 1, 1908). (On the durability of metal ties.)

"Steel Ties on the Bessemer & Lake Erie Railroad." Railway and Engineering Review, v. 48, p. 443 (June 6, 1908). (Give size of standard steel tie and experience in using it.)

"The Life of Steel Ties," by W. C. Cushing. (Railroad Age Gazette, v. 45, p. 24 (June 5, 1908). (Gives weight and size of ties used in various European countries, under heavy traffic.)

"Die Eisenschwelle," by A. Haarmann. Stahl und Eisen, v. 28, p. 177 (February 5, 1908). (History of the use of cross-ties and profiles showing development in size and weight.)

Translation of the same. "The Iron Sleeper," by A. Haarmann. The Engineer, v. 105, p. 189, 216 (February 21, 28, 1908).

"A Combination Steel and Concrete Tie on the Pittsburg, Fort Wayne & Chicago Railway." Engineering News, v. 63, p. 205 (February 17, 1910). (The weight of the tie is 800 to 850 lbs., there are fifteen of these ties in use, carrying a 33-ft. rail length of track.)

"Report No. 8 (Austria, Hungary, Bulgaria, Roumania, Servia and Turkey) on the Question of Strengthening the Track with a View of Increasing the Weight of Locomotives and the Speed of Trains (Subject II, Littera A, for discussion at the Eighth Session of the Railway Congress)," by Hermann Rosche. Bulletin International Railway Congress, v. 24, p. 1904, 1950 (May, 1910). (Gives speed of trains, wheel loads of locomotives and rolling stock and dimensions of sleepers.)

"Report No. 9 (all countries, except Austria, Hungary, Bulgaria, Roumania, Servia, Turkey, America and Great Britain) on the Question of Strengthening the Track with a View to Increasing the Weight of Locomotives and the Speed of Trains (Subject II, Littera A, for discussion at the Eighth Session of the Railway Congress)," by Blum. Bul. Inter. Ry. Cong., v. 24, p. 2497 (June, 1910). (Tables 1, 2 and 4 contain data on the length, weight, composition and speed of trains and dimensions and spacing of sleepers on twenty-one railroads.)

"Report No. 2 (Austria-Hungary, Roumania, Holland, Luxemburg, Germany and Switzerland) on the Question of Maintenance of Way on Lines with Heavy Traffic." (Subject IV for discussion at the Sixth Session of the Railway Congress)," by J. W. Post. Bul. Int. Ry. Congress, v. 14, p. 21 (March, 1900).

"Report No. 1 (Great Britain) on the Question of Strengthening the Track and the Bridges, with a View to Increasing the Speed of Trains" (Subject for discussion at the Eighth Session of the Railway Congress), by J. W. Jacomb-Hood. Bul. Inter. Ry. Cong., v. 23, p. 571 (July, 1909). (Contains two pages on cross-ties.)

"Report No. 4 (America) on the Question of Strengthening the Track and the Bridges, with a View of Increasing the Speed of Trains (Subject II for discussion at the Eighth Session of the Railway Con-

gress)," by M. L. Byers. Bul. Int. Ry. Cong., v. 23, p. 879 (September, 1909).

"Compound Sleepers on the Michel System," by Hector Michel. Bulletin International Railway Congress, v. 23, p. 1506 (November, 1909). (Contains results of experiments made on the Paris-Lyons-Mediterranean Railway, giving curves of deformation of various cross-ties, and determination of what length they should be.)

"La Superstructure des Voies des Chemins de Fer Allemands," by M. Blum. Revue Generale des Chemins de Fer et des Tramways, v. 31. Pt. 2, p. 277 (November, 1908). (Gives weight, size, material, etc., of cross-ties employed on railroads in Germany.)

"La Voie Courante des Chemins de Fer de L'Etat Belge," by Pierre Decamps. Revue Generale des Chemins de Fer et des Tramways, v. 32, Pt. 2, p. 251 (October, 1909). (Gives dimension of ties used by the Belgian State Railway in track for heavy and fast trains.)

"Two Foreign Developments in Railway Ties," Engineering News, v. 53, p. 204 (February 17, 1910).

"Railroad Track Superstructure (Editorial)", Railroad Gazette, v. 42, p. 326 (March 15, 1907). (A discussion of M. Cuenot's experiments.)

"Track Deformations and Their Prevention," by G. Cuenot. Railroad Gazette, v. 42, p. 363, 416, 453, 485, 517, 550, 588, 618, 654, 681, 713, 746, 801 (March 15, 22, 29; April 5, 12, 19, 26; May 3, 10, 17, 24, 31; June 7, 1907). (Describes experiments and gives conclusions deduced from them.)

"Note sur les Deformation Permanentes de la Voie," by M. Couard. Revue Generale des Chemins de Fer et des Tramways, v. 20, Pt. 2, p. 29 (July, 1897). (Contains a page on the influence of cross-ties on the deformation of railway track.)

"On Best Method of Maintaining the Track for the Tonnage and Speed of To-day." Proceedings of the Twenty-fourth Annual Convention of the Roadmasters and Maintenance of Way Association of America," 1906, p. 15, 40. (Report of the Committee with discussion.) Abstract of same. Railroad Gazette, v. 41, p. 459 (November 23, 1906).

"Steel Ties on the Bessemer & Lake Erie Railroad," by W. M. Camp. Proceedings of the Twenty-sixth Annual Convention of the Roadmasters' and Maintenance of Way Association of America, 1908, p. 59. (Discusses the size and weight of ties.)

"Kimball Concrete-Steel Ties." Railway Age, v. 44, p. 386 (September 20, 1907). (A type of concrete-steel tie subjected to the test of heavy traffic.)

"Versuche mit flusseisern Querschwellen in den Vereinigten Staaten von Nordamerika," by K. A. Mullenhoff. Zeitschrift des Vereines deutscher Ingenieure, v. 51, Pt. 1, p. 259 (February 16, 1907). (Describing and comparing ties and fastenings.)

"The Tie Problem with Special Reference to Concrete Ties," by G. H. Kimball, Journal Western Society of Engineers, v. 8, p. 561 (October, 1903). (Thirty-six pages.)

"Evolution des Voies de Chemins de Fer en Vue des Grandes Vitesees," by Mesanger. Genie Civil, v. 48, p. 93, (December 9, 1905). (Two pages.)

"Steel and Concrete-Steel Ties on the L. S. & M. S. Ry." Railway and Engineering Review, v. 46, p. 627 (August 18, 1906.) (Results of experiments and conclusions.)

"A Review of the Railway Tie Situation" (Editorial). Engineering News, v. 55, p. 500 (May 3, 1906). (Contains a brief reference to the size of ties.)

"Report of Committee on Ties." Proceedings American Railway Engineering and Maintenance of Way Association, p. 29. 35, 62, 68, 70, 72 (508-523), Chicago, Ill., 1906. (Contains report and discussion on the dimensions of ties.)

Extract of same. Railway Age, v. 41, p. 464 (March 23, 1906).

"The Carnegie Steel Tie." Railroad Gazette, v. 41, p. 64 (July 20, 1906). (Two pages, illustrated.)

"Concrete Railroad Ties," by G. H. Kimball. Cement Age, v. 2, p. 763 (April, 1906).

"Steel Cross-Ties," by W. F. Miller. Proceedings, Engineers' Society of Western Pennsylvania, v. 22, p. 69 (March, 1906). (Description of ties, giving size and examples of their use.)

"The Problem of Track Support," by Samuel E. Duff. Industrial World, v. 40, p. 301 (August 25, 1906). (Discusses cross-tie system of track support.)

"Note on the Economic Renewal and Maintenance of Railway Tracks for High Speed Traffic, Examination of a Vignoles Track, with Cramps, Wedges and Shock-Absorbers or Deadener Blocks," by L. Schlussel. Bulletin International Railway Congress, v. 21, p. 379 (April, 1907) (Discusses the effect of traffic on ties, etc.)

"Experiments with Reinforced Concrete Ties in America," by W. M. Camp. Bulletin International Railway Congress, v. 21, p. 861 (September, 1907). (Experience with ties for high-speed traffic.)

"What will be the Future Railway Track for Heavy Traffic?" (Editorial.) Engineering News, v. 53, p. 601 (June 8, 1905). (On the substitution of concrete longitudinals in place of cross-ties on tracks used for heavy traffic.)

"New Concrete Ties and Steel Ties." Engineering News, v. 54, p. 349 (October 5, 1905). (Tests under heavy traffic of concrete ties and steel ties; size is given.)

"Metal Ties in Germany," by A. Haarmann. Railroad Gazette, v. 35, p. 349 (May 15, 1903). (Description of ties used on an experimental road on the George-Marien-Hutten Railroad.)

"Steel Railroad Ties in Europe," by Foster Crowell. Railroad Gazette, v. 33, p. 600 (August 30, 1901).

"The Railroad Cross-Tie Problem," by S. Whinery. Railroad Gazette, v. 37, p. 526, 536 (November 4, 11, 1904).

"The Railway Tie Question." Engineering News, v. 50, p. 463 (November 19, 1903).

"Further Use of Steel and Reinforced Concrete Ties." Railway and Engineering Review, v. 44, p. 652 (September 10, 1904).

"Experiments with Steel and Reinforced Concrete Ties." Railway and Engineering Review, v. 43, p. 580 (August 1, 1903).

"The Effect on Track of Modern Equipment and High Speeds," by P. H. Dudley. Railway Age, v. 35, p. 409 (March 20, 1903). (Contains references to the effect of traffic on ties.)

EXHIBIT G.†

Species	Air Dry — Compression Vertical to Grain					Green — Compression Vertical to Grain				
	Stress Area, In.	Height, In.	No. of Tests	Per cent Moist.	Cr. Str. at E.L. lbs. per sq. in.	Stress Area, In.	Height, In.	No. of Tests	Per cent Moist.	Cr. Str. at E. L. lbs. per sq. in.
1. Longleaf Pine....	4x5	4	22	25.1	572	4x4	4	22	25.3	568*
2. Douglas Fir.....	4x8	16	44	20.8	732	4x8	16	259	30.3	570
	4x8	10	32	18.1	584	.....	.....	.....	.....	.....
	4x4	8	51	20.2	638	.....	.....	.....	.....	.....
	4x4	6	49	24.0	613	.....	.....	.....	.....	.....
							(Fire	killed)		
	4x4	4	29	24.8	603	6x8	16	24	33.7	368
3. Shortleaf Pine...	8x5	16	4	17.8	725	5x8	16	12	37.7	361
	8x5	14	3	16.3	757	5x8	14	12	42.8	366
	8x5	12	5	15.1	730	5x8	12	24	53.0	325
	5x5	8	6	13.0	918	5x5	8	24	47.0	344
	2x2	2	57	13.9	926	5x2	2	277	48.5	400
4. Western Larch...	.....	.....	.....	.....	.....	6x8	16	22	43.6	417
	.....	.....	.....	.....	.....	6x8	12	20	40.2	416
	.....	.....	.....	.....	.....	4x6	6	53	52.8	478
	.....	.....	.....	.....	.....	4x4	4	30	50.4	472
5 Loblolly Pine...	8x5	16	12	19.8	602	8x4	8	16	67 2	392
	8x5	8	7	22.9	679	4x4	8	38	44.6	546
	4x5	8	8	19.5	715	.....	.....	.....	.....	.....
6. Tamarack.....	2x2	2	57	16.2	697	.....	.....	.....	.....	.....
7. Western Hemlock	7x6	15	25	18.2	514	6x4	6	30	48.7	434
	6x6	6	26	16.8	431	.....	.....	.....	.....	.....
	4x4	4	6	15.9	488	.....	.....	.....	.....	.....
8. Redwood.....	.....	.....	.....	.....	.....	6x8	16	13	86.7	473
	.....	.....	.....	.....	.....	6x6	12	14	83.0	424
	.....	.....	.....	.....	.....	6x7	9	13	74.7	477
	.....	.....	.....	.....	.....	6x3	14	13	75.6	411
	.....	.....	.....	.....	.....	6x2	12	12	66.5	430
	.....	.....	.....	.....	.....	6x2	10	11	55.0	423
	.....	.....	.....	.....	.....	6x2	8	12	56.7	396
	.....	.....	.....	.....	.....	2x2	2	186	75.5	569
9. Norway Pine....	2x2	2	36	10	924	.....	.....	.....	.....	.....
10. Red Spruce.....	.....	.....	.....	.....	.....	2x2	2	43	31.8	310
11. White Spruce....	.....	.....	.....	.....	.....	2x2	2	46	50 4	270

* Partially air dry.

† See United States Department of Agriculture, Forestry Service Circular 189, Forestry Products Laboratory, Series issued January 25, 1912, "Strength for Structural Timbers."

EXHIBIT F.

SUMMARY OF REPLIES RECEIVED IN ANSWER TO CIRCULAR REGARDING SIZE OF CROS TIES REQUIRED FOR THE STRESSES TO WHICH THEY ARE SUBJECTED.

Line No.	Name of Railroad.	Officer and Title.	Mileage.	1 What percentage of a rail length should have a bearing on the ties?	1a Does per cent. me per cent. of linear d tance or bearing area?
1	American Creosoting Co.....	A. L. Kuehn, General Superintendent.	.....	It is not proper to state rail length should ha This depends on sub-soil and weight of rail.	that a fixed per cent ve a bearing on t , ballast, kind of wo
1a	A. T. & S. F.....	R. J. Arey, Engineer Grand Division.	10208	40 per cent.....	Linear distance....
2	B. & O.....	E. Stimson, Chief Engineer Maintenance of Way.	4724	36 per cent. for oak and other ties of similar crushing strength.	Per cent. of linear d tance.
3	B. & O.....	A. W. Thompson, General Manager.		Same all through, as No. 2.	
4	B. & A.....	Moses Burpee, Chief Engineer.	628	About 30 per cent.....	Linear distance be ing area increased by of tie-plates.
5	C. & E. I.....	L. C. Hartley, Chief Engineer.	966	40 per cent.....	Linear distance....
6	C. & N. W.....	C. L. Ransom, Res. Engineer.	9686	No data.	
7	C. B. & Q.....	G. H. Bremner, District Engineer.	8966	40 per cent.....	Of the linear dista or total area of base rail.
8	C. R. I. & P.....	J. M. Brown, Engineer Maintenance of Way.	8020	40 per cent. The reason I think it is 40 per cent. is that is about as many ties as can be reasonably put under the rail.	Linear distance....
9	C. R. I. & P.....	Garrett Davis, Superintendent.	.....	40 per cent.....	Linear distance....
10	C. R. R. of N. J.....	Jos. O. Osgood, Chief Engineer.	670	41 per cent. This is based on the use of 18 ties per 33-ft. rail. Face of ties 9 in.	Linear distance....
11	D. & R. G.....	A. O. Ridgway, Asst. Ch. Eng.	2778	Probably 40 to 45 per cent.	Per cent. linear d tance.
12	E. P. & S. W.....	J. L. Campbell, Engineer Maintenance of Way.	902	We have 40 per cent...	Linear distance.. .
13	G. T.....	M. S. Blaiklock, Eng. M. Way.	4757	45 per cent.....	Linear distance....
14	I. C.....	D. W. Thrower, Roadmaster.	2245	35 per cent. to 40 per cent.	Bearing area.....
15	K. & M.....	R. P. Black, Engineer Maintenance of Way.	175	50 per cent.....	Bearing area.....
16	L. S. & M. S.....	Sam'l Rockwell, Chief Engineer.	1663	45 per cent.....	Per cent. of linear d ance.....
17	L. V.....	E. B. Ashby, Chief Engineer.	1432	40 per cent. at least....	Linear distance.....

EXHIBIT F—Continued.

Name of Railroad.	Officer and Title.	Mileage.	1 What percentage of a rail length should have a bearing on the ties?	1a Does per cent. mean per cent. of linear distance or bearing area?
L. & A.	F. W. Green, General Manager.	260	About 40 per cent.	Linear distance.
L. & N.	T. Maney, General Roadmaster	4590	40 per cent.	Linear distance.
M. C.	G. F. Black, Engineer Maintenance of Way.	932	33⅓ per cent.	Linear distance.
M. R. & B. T.	C. H. Fake, Chief Engineer.	46	Most of my experien one kind of timber and used, and a class of bal roads, therefore what o made would not be of	ce has been where but one size of tie has been last used on but few bservations I may have general value.
M. P.	J. R. Leighty, Engineer Maintenance of Way.	7236	Cannot answer this question definitely. See below.	Linear distance.
N. Y. C. & H. R.	J. V. Neubert, Engineer Track.		From ⅛ to ¼.	Bearing area.
N. Y. C. & H. R.	Geo. W. Vaughan, Engineer Maintenance of Way.	2829	The answers to No. 1 bit on the spacing of the trains, and whether or course it is assumed that as loblolly, cypress, plated in all main	and No. 1a depend a good tie, axle load, speed of not ties are tie-plated. Of all soft wood ties, such cedar, etc., will be tie-tracks.
N. Y. C. & H. R.	Geo. W. Kittredge, Chief Engineer.	.....	45 per cent.	Per cent. of length of rail.
N. Y., N. H. & H.	H. L. Ripley, Engineer of Construction.	2047	It seems to me the questions is almost a ma ment or experiment on a piece of track under the tory expert.	answer to most of your tter of laboratory experi- n especially prepared observation of a labora-
N. & W.	C. S. Churchill, Chief Engineer.	1951	36.4 per cent.	Linear distance.
N. & W.	G. W. Merrell, Assistant to General Manager.	.....	40 per cent. without tie-plates; 30 per cent on plates.	Linear distance.
Penna. Lines, S. W. System	W. C. Cushing, Chief Engineer Maintenance of Way.	2889	41 per cent.	Linear distance.
Penna. Lines, N. W. System.	R. Trimble, Chief Engineer Maintenance of Way.	.....	See No. 3.	There is no difference.
P. & R.	R. B. Abbott, Division Engineer.	1509	About 40 per cent.	Linear distance.
P. & R.	F. S. Stevens, Engineer Maintenance of Way.	.....	30 per cent. to 35 per cent.	Linear distance.
P. & L. E.	J. A. Atwood, Chief Engineer.	215	45 per cent.	Linear distance.
P. & L. E.	Edwin F. Wendt, Assistant Engineer.	.....	Some time ago the New York Central Lines Maintenance of Way Committee recommended that 45 per cent. of the length of the rail should be supported by cross-ties. This means 45 per cent. of the linear distance.	.....

Line No.	Name of Railroad.	Officer and Title.	Mileage.	1 What percentage of a rail length should have a bearing on the ties?	1a Does per cent. mean per cent. of linear distance or bearing area?
35	Q., M. & S.	F. D. Anthony, Chief Engineer.	192	43 per cent	Linear distance
36	R., F. & P.	S. B. Rice, Engineer Maintenance of Way.	89	Not less than 34 per cent.	Linear distance
37	S., P. & S.	R. Budd, Chief Engineer.	433	Approximately 40 per cent.	Linear distance
38	W.-P. T.	W. F. Purdy, Chief Engineer.	64	36 per cent. to 40 per cent.	Bearing area, but with full face ties should be same for both.
39	W. M.	J. Carmichael, Engineer Maintenance of Way.	543	35 per cent	Linear distance, 90-lb. rail A. S. C. E, section.
	Total replies received, 40. Per cent. of membership, 4 per cent. Per cent. of mileage, 32.	Total mileage	83644		

Line No.	2 Has this percentage any relation to (a) Kind of timber used for ties?	(b) Kind of ballast?	(c) Character of sub-grade?	(d) Tangent vs. Curve?	(e) Minimum distance between face of ties?
1	Yes, there should be sufficient ties so that the wood will not be stressed beyond a proper working limit.	Yes, the distributing power of the ballast will affect the number of ties to be used.	Yes, the sustaining power of the sub-grade will affect the proper number of ties to be used.	Yes, sufficient ties should be used to take care of the excess loading at curves.	Six inches
1a	Yes	Yes	Yes	Yes	Twelve inches
2	Yes, it is dependent upon strength of timber. Tie-plates should be used to distribute the load upon the ties made from weaker woods.	Yes, inasmuch as stone ballast has greater carrying capacity and is less inclined to motion under load and impact, the percentage may be less than it would be with gravel or sand.	It may vary with the bearing capacity of sub-grade.	Practically none	Yes, dependent upon material used for ballast and its liability to motion.
4	No, use practically only soft woods. Mostly white cedar, and classification would be impossible.		No	Usually slightly increased on curves.	Ten inches
5	No	No	No	No	Eight inches
7	Yes	Inferior ballast should have greater bearing.	Yielding sub-grade should have greater bearing.	Greater bearing surface needed on curves.	Twelve inches

Line No.	2 Has this percentage any relation to (a) Kind of timber used for ties?	(b) Kind of ballast?	(c) Character of sub-grade?	(d) Tangent vs. Curve?	(e) Minimum distance between face of ties?
8	This percentage has no or the alinement.	relation to the timber in	the ties, kind of ballast,	character of sub-grade	The minimum distance between the face of ties is about 12 in. and this necessarily cannot be very much less as if narrower than that it would interfere with the use of the shovel in taking care of the ballast, and the width of the shovel is about 10 in. Apparently this would look as though the minimum distance between ties at the present day is determined by the width of the shovel. I do not believe, however, the standard on this railroad differs materially from that on other roads, and if ties were placed much closer together it would be difficult to tamp the ballast under them.
9	No.....	No.....	No.....	No.....	Thirteen inches.....
0	Practically not, because spacing of ties is fixed by other conditions.	Practically not, although ties might be placed closer on gravel or sand, where tamping is less difficult than with stone or slag ballast.	Not if ballast is sufficiently deep to properly transfer weights to subgrade.	Yes, but impracticable to make such change on account of tamping requirements.	Joints 9 in. Intermediate 13 in.
1	To some extent.....	To some extent.....	No.....	Yes.....	Yes.....
2	No, we are using principally treated pine ties.	Rock, slag and gravel.	Generally sandy and gravelly earth and loam.	No distinction.....	Eleven inches.....
3	None.....	Gravel.....	Clay.....	Both.....	Ten inches.....
4	Not if tie-plates are used of proper width and length. If tie-plates are not used, very soft ties should be placed close together.	Yes, number of ties depends on the efficiency of gravel. Cementing gravel and slag require less bearing area for the rail.	Yes.....	Percentage should be increased on curves.	Ten inches.....
5	Good hardwood timber ties.	Stone or gravel.....	Average earth.....	Both.....	Ten inches.....
6	It applies to standard conditions for each particular piece of main track, which may vary with character of business done over that track.	This varies with standard of each particular piece of main track as above.	This also varies as per *a*.	We use same number of ties for rail on tangents as on curves.	See standard blue print attached and marked "F-1."
7	No.....	No.....	No.....	No.....	Maximum, 13½ in.....
8	Yes, based on white oak ties, 6x8x8. Per cent. should vary inversely as resistance of wood to crushing.	Yes, it should vary inversely as the firmness of the ballast.	Yes, same as for ballast.	Not for curves of less than 8 or 10 degrees.	Yes, inversely as thickness of tie.

Line No.	2 Has this percentage any relation to (a) Kind of timber used for ties?	(b) Kind of ballast?	(c) Character of sub-grade?	(d) Tangent vs. Curve?	(e) Minimum distance between face of ties?
19	No, because it is the maximum bearing area that admits proper tamping.	No, for reason under *a*.	No, for reason under *a*.	No, for reason under *a*.	Yes, because it leaves the minimum space between ties within which proper tamping may be done.
20	Strictly with regard to stresses, yes.	Greater bearing surface probably needed in soft ballast.	Greater bearing surface probably needed in soft sub-grade.	No.....	Greater bearing surface probably needed with thin ties.
22	Yes, resistance of timber to cutting is big factor.	Do not think this is a factor as far as ties only are concerned, except that wave motion of rail and consequent rail cutting of ties vary with different kinds of ballast.	Same as *b*.....	Increased tendency of rail to cut ties on curve as compared to tangent would require more ties on curves than tangents to maintain same conditions.	Depending on ballast and roadbed and kind and size of ties.
25	No, if tie-plates are used, otherwise percentage would vary with hardness of ties.	Independent of kind of ballast, provided it is first-class and is sufficient in quantity.	Not if ballast of sufficient quantity and quality is used.	With proper elevation bearing on curve and tangent should be treated the same.	About 7 in.....
27	We use only hardwood ties and above data refer to them.	Stone, slag, gravel, cinder.	Existing sub-grade is now generally old ballast.	We make no distinction except to use tie-plates on curves.	Joint ties 10 in., intermediate ties 12 in.
28	White oak.	Stone or coarse gravel.	.....	Both.....	Ten inches.....
29	No. Tie spacing limited by minimum distance between face of ties required for tamping.	No. See *a*.	No. See *a*.	No. See *a*.	Yes. This is the governing point.
31	Based on sawed ties (yellow pine).	No.....	No.....	No.....	Thirteen inches.....
32	No, because no greater percentage can be used without too much encroachment on room needed for tamping. If ties are soft use larger tie-plates.	Less ties might be used on stone ballast of great depth, but where these conditions prevail traffic is generally so heavy that full complement of ties is needed.	Bearing surface not affected, but if sub-grade is hard less depth of ballast is permissible.	If superelevation of curves is adjusted to speed, centrifugal force and gravity are in equilibrium and bearing surface should not be changed.	Ten inches.....
33	No.....	No.....	No.....	No.....	There should not be less than 10 in.
34	Our road has used nothing but white oak timber in the past.	Stone ballast is used.	The sub-grade is 3 ft. below top of rail and this 3 ft. is made up of track one foot, ballast one foot, sub-ballast one foot. Our road uses 20 ft. roadbed, 10 ft. on each side of center line, in accordance with the standard of the Engineering Association.	We make no difference in the spacing of ties on tangent or curves. All track is treated the same	The distance between face of cross-ties is 12 in. We think this distance gives an opportunity for tamping with a tamping pick and our present rule is to space ties 12 in. apart, which means about 20-in. centers. The 45 per cent. rule is not carried out absolutely. Ties spaced 12 in. apart are practically in accordance with the spirit of this rule.
35	No.....	No.....	No.....	No.....	Eleven inches.....

2				
Has this percentage any relation to				
(a) Kind of timber used for ties?	(b) Kind of ballast?	(c) Character of sub-grade?	(d) Tangent vs. Curve?	(e) Minimum distance between face of ties?
Certainly. It would depend entirely on class of timber used. For soft woods per cent. of bearing should be increased if tie-plates are not used.	Yes, the less bearing properties the ballast has the greater the per cent. of supported rail length should be.	Yes. In rock cuts, hard clay, etc., bearing per cent. can be at a minimum of 34 per cent.; on wet, soft roadbed, bearing per cent. should be increased.	The bearing surface should be increased on curves exceeding a 3 degree.	18 ties and 17 spaces to 33-ft. rail.
No.....	No.....	No.....	No.....	No.....
Probably some advantage from larger bearing area on soft ties, but not in same ratio. Poor ties make poor track, no matter how many be used.	Some advantage from high-grade ballast with wide spacing of ties, but much greater benefit derived from good ballast if full bearing surface be provided at same time.	Yes; with uniformly good, firm sub-grade, smaller per cent. of bearing surface may be provided.	Higher per cent. on curves especially of short radius, more on account of gain in holding alinement than for bearing.	Twelve inches; less will interfere with tamping.
No. Tie-plates are used on soft woods.	No.....	No.....	No. Hardwood ties and tie-plates used on curve.	Fifteen inches.....

3	4	5	6	7
If the percentage is capable of mathematical deduction, please give the method.	Is crushing hastened by natural checking of ties?	What class of wood checks most?	Does preservative treatment tend to increase the tendency to check?	Does preservative treatment affect the natural crushing unit stresses?
No, excepting very crudely.	Yes, the crushing strength across the grain is reduced by checking.	Wood which seasons rapidly usually checks the most; wood like beech and gum will check more than oak.	Not when wood is air-seasoned and treated without steaming. If wood is steamed in treatment, checking will usually be more rapid.	Not if wood is air-seasoned for treatment and not steamed.
.....	To a large extent.....	Hardwood; in oak, ash, elm, eucalyptus.	No.....	Yes, should be determined by actual tests.
.....	Yes.....	Red oak family, gum, beech, chestnut and other inferior woods.	In these woods naturally liable to checking in seasoning the use of salt solution preservative likely increases the tendency to check.	No apparent difference between treated and untreated timber.
.....	We do not find checking of ties to any extent.	.....	Are not treating ties to any extent.	.....
Based on 20–6x8 ties to 33 ft. rail and 18–7x9 ties to 33-ft. rail.	Believe checked ties would naturally crush more easily than solid timber.	.....	Have not noticed that treatment by creosote has any great effect in this way, but believe that checking is increased when timber is treated by the zinc chloride process.	Have been advised by the track supervisors that they believe the creosote treatment has a tendency to soften the wood and make it more easily crushed. Have not confirmed this, and am unable to express a conclusion.
.....	Yes, by allowing decay to start.	.....	Yes.....	.....

Line No.	3 If the percentage is capable of mathematica deduction, please give the method.	4 Is crushing hastened by natural checking of ties?	5 What class of wood checks most?	6 Does preservative treatment tend to increase the tendency to check?	7 Does preservati treatment affect the na ural crushing unit stres es?
8	I do not think this percentage is capable of mathematical deduction, there being too many indeterminate factors. Furthermore, within a few years a great many of our ties become so deteriorated they do not retain, by a large percentage, the same efficiency in supporting the rail that they do when new.	Crushing is no doubt hastened by natural checking of ties.	Hardwood checks more readily than soft.	Treated ties have a greater tendency to check than untreated ties.	I am not prepared say whether treated ti are capable of sustaini less unit crushing stre than untreated ties. A parently, the wood rendered somewh more brittle by treatir
9	18 ties per 30-ft. rail is about right for proper tamping.	Yes.....	.....	No.....	No, think not, b never tested it.
10	Too many theoretically indeterminate factors to reduce to a formu a.	Yes.....	Yellow pine, untreated (oak, chestnut and yellow pine in use).	No.....	Slightly, if at all....
11	Do not consider the matter capable of mathematical deduction.	Probably only in so far as checking hastens decay.	Have not had experience with all classes of wood.	I understand it does, but cannot speak from personal observation.	Have made no tests.
12	.....	Apparently so, especially over-treated ties where the wood has been steamed too much and zinc chloride used.	Pine ties over-treated, as per No. 4.	Zinc chloride and high temperatures naturally increased the checking of our pine ties. We now use creosote only without steaming and this diminishes checking.	Apparently it does, al diminishes holding po er of driven spikes.
13	.....	No.....	Red oak.....	No.....	Yes, some processe particularly creoso oils.
14	.....	Yes, checking allows ties to disintegrate faster, consequently hastens crushing.	Beech, oak, gum, maple, walnut, locust.	Yes, to great extent, beech and red oak ties.	Yes, but to small tent, varying with diffe ent types of treatment.
15	.....	Yes.....	Elm.....	Lessens check.....	No.....
16	Problem too much complicated by independent variables.	Not unless checks come close to edge.	Beech, maple, hickory.	The checking occurs while ties are seasoning and so before treatment.	Preservative trea ment softens the ti while the ties are w from the treatment, they crush more easi until they become dr
17	Need all the ties under a rail that can be used and leave room for proper tamping. No mathematics used to determine this.	No.....	All hardwoods check, beech, birch and maple the worst.	No, ordinarily, but if heavily steamed; under old process, yes.	No.....
18	Too many interdependent variables to attempt it.	Yes.....	Post oak worse than white oak. In general, wood with highest moisture ratio checks the most.	Do not believe it does.	Believe it somewh decreases elastic limit compression, especial in loblolly and yello pine ties.

EXHIBIT F—Continued.

3	4	5	6	7
If the percentage is capable of mathematical deduction, please give the method.	Is crushing hastened by natural checking of ties?	What class of wood checks most?	Does preservative treatment tend to increase the tendency to check?	Does preservative treatment affect the natural crushing unit stresses?
Cannot be mathematically deduced because of the widely different character of sub-grade, ballast, stiffness of rail, weight of loads, etc.	Yes, directly by the separation of the fiber, and indirectly by decay, which follows.	Of those within my knowledge, oaks.	Think not.....	Possibly creosote softens the wood.
Percentage given is a matter of personal judgment and observation only.	Yes.....	Our experience is almost wholly with cedar.	Practically no experience with treated ties.	.....
I think the consideration should start from the roadbed and the traffic to carry and the kind (size) of rail to carry it, to get the maximum carrying capacity of track; the wheel load should be distributed uniformly over the roadbed. This involves a relation between distance between ties and depth of ballast. The proper relation is the one which will give uniform distribution at the least cost for investment and maintenance and is dependent upon the relation of cost of ties and ballast.	I think so.....	Do not know.....	Zinc treatment seems to.	Do not know.....
.....	Yes.....	The majority of our ties used are yellow pine, and they check.	We have only been using treated ties to any extent for two years, so cannot give satisfactory reply. If properly treated and a suitable tie-plate to provide for mechanical wear, I should think the checking would be decreased. This will also answer No. 7.	Answered by No. ...
The percentage is a matter of experience and experiment rather than mathematical deduction.	I believe it is.....	The harder class of oaks would, in my opinion, check most.	I do not know.....	I do not know.....
We have given above our general practice, which has proved successful.	We think not materially in hardwood ties.	Chestnut, of which we use very few.	We have not had experience with treated ties.	No data.....
.....	Somewhat..... ..	Soft.....	.....	.....
.....	Yes.....	Do not know.....	Not with creosote, unless excessive steam pressures are used. The zinc chloride process probably increases tendency to check, as it increases the moisture content of the wood.	Decreases crushing strength but very little unless excessive heating takes place in the treatment.

Line No.	3 If the percentage is capable of mathematical deduction, please give the method.	4 Is crushing hastened by natural checking of ties?	5 What class of wood checks most?	6 Does preservative treatment tend to increase the tendency to check?	7 Does preservative treatment affect the natural crushing unit stresses?
30	Percentage of bearing is dependent on tie spacing, which must be such as to permit of tamping. On the Pennsylvania Lines we use 18 ties to a 33-ft. rail, which gives a distance face to face of ties of 14¼ in. This gives (with 8-in. ties) 36.3 per cent. of base bearing on ties.	We have no evidence that it is.	Of woods now used extensively by the Pennsylvania Lines, i. e., oak and yellow pine, oak checks most. Chestnut, formerly used extensively, checks more than oak.	No.....	No.....
31	Clearance needed for tamping is the determining factor. This space between ties should be made as small as possible.	Not to any great extent.	We use pine, oak and chestnut; oak checks the most.	No; it decreases it.	The wood is usually made softer by the preservatives to a depth of about ½ in. to ¾ in. The net resistance to crushing is thereby reduced and the unit stress increased.
32	Conditions vary through wide range. No mathematical deductions can be of much value.	Checking permits entrance of moisture that causes decay and therefore hastens crushing.	Yellow pine.....	No.....	It prevents checking and therefore increases resistance to crushing to some extent.
33	.....	Don't know.....	Don't know.....	Don't know.....	Don't know.....
34	It is probable that this percentage was not worked out mathematically and no doubt it represents about the maximum amount of timber which can be used under rails in order to leave sufficient opening between the ties to give the trackman proper opportunity to successfully tamp the ballast with tamping picks.	We have noticed little or no crushing where white oak ties are used.	No answer is given, because our experience has been confined to the use of white oak ties.	Whether preservatives increase the tendency to check is the question which we cannot answer, because in the past treated ties have not been used.	See No. 6.....
35	Basis of 7-in. x 9-in. ties on the flat and 12-in. working room between ties.	Yes. Particularly as checking hastens decay.	(Experience in the soft northern timber only.)	Not enough experience to permit of reply for favorable comparison.	Not enough experience to permit of reply for favorable comparison.
36	....	To a very small extent.	My experience has only been with chestnut, white and post oak; of these three, chestnut has the greatest tendency to check.	Can't say. No experience.	.....
37	No	Yes.....	Fir.....	Yes.....	Lessens unit crushing stresses.
38	Have no method except observation, experience, and results of both.	Not appreciably in good white oak. It is, to some extent, in soft or unsound woods.	Hard, tough-grained wood.	Have not sufficient experience to state; do not think so.	.....
39	33-ft. rail equals 396 inches long, 17 ties per rail with 8-in. face 136 in., percentage .344.	.....	.....	No experience with preservatives.	.....

No.	8a	8b	9	10	11
	With the increased consumption and the decreased available supply, can the demand for large sectional area of ties be met?	If a large sectional area of tie is not available, what would you recommend as next best thing to do, use steel, or composite, or what not?	Has the application of screw or square spikes any effect on crushing?	Relation of kinds of ballast to tie-crushing.	Relation of character of sub-grade to tie-crushing.
1	It may be met in territories where tie-making has not yet become a large industry. It will be difficult when all present tie sizes are well established.	The present wood tie sections are sufficient if used in the proper number to give proper bearing, which is entirely feasible. Ballast depth must, however, be much increased. It is feasible and within limits of proper economy to place enough 6″x8″x8′ wood ties under track to properly sustain axle loads, which the present kind of steel rail will sustain (per wheel) without excessive flowing.	If the rail is held closely to the tie, wearing or crushing is reduced. The only means of doing this is to use screw spikes.	Ballast which is firm and drains quickly and which allows only a small amount of motion will reduce crushing. Dry timber is stronger in resisting crushing than wet timber.	Same as No. 10.....
a	Demand can be met for a number of years.	Use reinforced concrete or steel.	Have no data for comparison.	Have data available but think that the more yielding materials have less tendency to tie-crushing.	The better the sub-grade, the less the ties have tendency to crush.
2	The decreased production which is indicated by United States forest service reports is due to diminished supply and indicates that it will be difficult to secure a requisite number of ties of larger sectional area.	As a first resort, use ties spaced narrowly.	Screw spikes properly driven or used with threaded plugs would preserve the wood fiber and naturally tend in some degree to increase crushing strength.	Stone ballast with its greater bearing capacity reduces impact and consequently also reduces tendency to crush. Gravel and other ballast composed of small pieces tend to increase the load and further tie-crushing.	This relation would be similarly indicated by a variation in bearing capacity of sub-grade.
4	Not without a radical change in practice or price.	I do not think a satisfactory substitute for wood has been brought out, but I think a composite tie using wood cushion for rail will be necessary.	.....	.....	....
5	Probably locally but not generally for many years.	Believe this is a question that will have to be solved soon, but so far as my knowledge goes, a solution has not yet been found. Apparently the practice of treating ties will conserve the available timber supply, at least temporarily.	Naturally, yes; but cannot say from experience as to the comparative effects of the two kinds of spikes; would suppose it preferable to use screw spikes, and it is not necessary to redrive them so often, thereby not breaking up the fiber and spike-killing the tie.	Crushing is probably greater in stone and slag ballast than in gravel and other lighter ballasts, on account of the more rigid tamping.	The character of the sub-grade would evidently have an effect upon tie-crushing, since a hard sub-grade with rigid ballast would give greater crushing stress with the impact.
7	Yes, as it is counterbalanced by increase of timber preservation.	It is available at the present time.	.....	.....	.....
8	I do not believe we can demand a larger sectional area per tie, as the cost per tie is increased, not only by the additional size of the tie, but by the additional cost for handling and applying, and increased amount of ballast (if tie is lengthened).	I do not believe we are prepared to give up yet the use of the wood tie and adopt one of some other material, but by the use of heavier rail and tie-plates we can still continue to use the ties that we have, reducing the number to the rail by one or two if rail of 100 lbs. or greater weight per yard is used. Greater care should be exercised in the applying of ties and applying of tie-plates, and I think holes should be bored even for the insertion of square spikes, all of which will tend to increase the life of the tie.	We have no screw spikes in this territory.	The most severe crushing in my experience has been in gravel ballast, but that was due to the frequency of passenger trains and heavy freight traffic, which are the greatest factors in crushing of ties. I would not put this forward, however, as an opinion that gravel is more severe than other ballast on ties.	The life of tie is increased by having better ballast, and, necessarily, better ballast follows if there is a good sub-grade.

EXHIBIT F—Continued.

Line No.	8a With the increased consumption and the decreased available supply, can the demand for large sectional area of ties be met?	8b If a large sectional area of tie is not available, what would you recommend as next best thing to do, use steel, or composite or what not?	9 Has the application of screw or square spikes any effect on crushing?	10 Relation of kinds of ballast to tie-crushing.	11 Relation of character of sub-grade to tie-crushing.
9	No.....	Can't say.....	Not that I know.....	.....	.....
10	No.....	Use heavier rail with tie-plates of ample size and thickness on all ties. Adapt the number of ties to suit the weight of the rail section as far as limitations of tie spacing will permit.	Square spikes injure the fiber of the wood and therefore promote softening around the rail-seat which reaches out under the entire base of the rail, promoting decay and crushing.	Doubtless contributes to some extent to tie-crushing, but the difference in this respect between various kinds of ballast is not great.	A poorly drained and soft sub-grade is injurious in permitting movement of the ballast.
11	In my opinion it can be met for some years to come.	Neither a steel nor composite tie has been found which will entirely meet all requirements. Believe energies should be directed towards design of a composite tie.	Have had no experience with screw spikes, but believe screw spikes would possess some advantages in this respect.	Have no definite records.	With proper depth and character of ballast, cannot see any relation.
12	Yes, by consuming the supply proportionately faster.	Am decidedly of the opinion that the coming tie will be a steel or iron tie. Do not expect to see concrete come into general use.	Don't know.	Have observed no relation.	Would not expect ties to crush much on soft Missouri mud.
13	Yes, by reducing thickness and increasing stability of tie-plate.	Use steel.....	Yes, by reducing the sawing motion between rail and tie.	.....	.....
14	In my opinion, yes.	Do not consider time has arrived for elimination of wooden ties.	No experience with them. My opinion is that screw spikes would appreciably reduce crushing.	Ties crush more in rock slag and cementing gravel than in loose or other classes.	The more resilient the sub-grade the less ties crush.
15	Yes.....	Steel.....	On account of destroying more or less fiber structure it should slightly increase crushing.	Stone first, hard slag and cinders given in order of ballast that gives most tie-crushing.	The better sub-grade the less tie-crushing.
16	Increasingly harder to get large ties.	Tie-plates and more ties.	.....	The better the ballast the less crushing will occur.	The better the sub-grade the less crushing of ties.
17	No.....	Use more ties.....	No experience.....	The less elastic the ballast the more the ties will crush; also the firmest ballast and the higher the section of rail the faster the rail will wear down and this must be met by hardening the steel in the rail in proportion to increase in stiffness of rail section.	Ties will crush easier on rock sub-grade, especially where ballast cushion is insufficient.
18	Do not think it practicable.	Doubt if any substitute will ever be found for wood ties. Steel O. K. in certain special cases. I think ties will be imported sometime from South America, Africa, etc.	Do not think effect would be perceptible.	In general, the crushing should vary directly as the axle load, the rigidity of the ballast and sub-grade and as the rail deflection.	See No. 10.....

EXHIBIT F—Continued.

8a	8b	9	10	11
With the increased consumption and the decreased available supply, can the demand for large sectional area of ties be met?	If a large sectional area of tie is not available, what would you recommend as next best thing to do, use steel, or composite or what not?	Has the application of screw or square spikes any effect on crushing?	Relation of kinds of ballast to tie crushing.	Relation of character of sub-grade to tie crushing.
Think not, economically.	Use a plate large enough to distribute the load and of such construction to permit the readjustment of the rail without disturbing the initial seat of plate on the tie.	Think the displacement of any part of the wood under or about the rail tends to weaken.	Hard, unyielding ballast increases tendency to crush.	Same as of ballast.
Hardly.....	Would recommend using the area that is available and do not know yet what to recommend as a substitute.	We use no screw spikes; square spikes where used in skimming as much as necessary in some cases increase tendency to crush.	Think it worse in soft ballast due to greater wave motion of rail.	Think it worse in soft sub-grade due to increased wave motion of rail.
For a time, yes, until it commences to affect the lumber output; even then it is only a question of price.	Do not think the size of tie is a factor, except as to thickness. I think the bearing area on roadbeds and rail is the only thing to consider, and this is controlled by distance between ties.	Do not know.....	If this includes breaking, the softer the roadbed or ballast, the greater the tendency to break; the harder the ballast, the greater the tendency to break.	Same as No. 10.....
The demand for wooden ties cannot be met, unless ties suitable for treating are available.	Use steel or tie of some other composition of permanent construction that is to take care of our side-track needs. The operation of trains under high speed in various weather conditions, etc., will not permit the use of above tie with safety.	Have not been used sufficient length of time to determine. If properly supplied with tie-plates, I think the crushing would be less.	Ties crush or check under stone ballast with the same traffic as under cinders, gravel, etc. This on account of track being more rigid. This on the assumption that all the ballast mentioned above has good drainage. This also answers No. 11.	Answered by No. 10..
This is purely a matter of dollars and cents; large ties can undoubtedly be obtained if it is worth the additional cost involved.	Am open to conviction. I have not seen any tie for substitution for wood that I can unconditionally approve.	Probably the crushing would be greater with spike than screw because of more vertical movement after having been in use a short time.	I believe a good gravel ballast is better than a stone ballast to reduce the tie-crushing.	The harder the sub-grade, the greater would naturally be the crushing tendency. With sufficient ballast the effect of sub-grade upon crushing can be eliminated.
We think ties having a face width of from 7 in. to 9 in., thickness of 7 in., length of 8 ft. 6 in., spaced 18 to a 33-ft. rail, joint ties 17 in. c. to c., intermediate 24 in. c. to c., with tie-plates for heavy loads and traffic, are sufficient, and such are procurable.	We have not investigated other than wood ties.	No data.....	Our ties are removed on account of decay, rather than crushing or cutting. Cutting of ties is kept down by use of tie-plates. And we think there is not much variation due to ballast.	Very remote with fair ballasted track.
Yes, by treating soft ties.	.....	Not with tie-plates of proper width and thickness.	.....	.....
Probably not; at least not for an unlimited length of time.	Composite.....	Indirectly, yes. The cutting and disruption of the fibers of the wood by the spikes opens up wood and hastens process of decay, which reduces crushing resistance and facilitates the mechanical wear of the wood. Square spike has much greater effect than screw spike.	The more rigid and unyielding the ballast, the greater the tie crushing. Tie-crushing is greater, therefore, under stone ballast than under gravel.	The more yielding and elastic the sub-grade, the more give there is to the tie, resulting in less tie crushing.

	8a	8b	9	10	11
	With the increased consumption and the decreased available supply, can the demand for large sectional area of ties be met?	If a large sectional area of tie is not available, what would you recommend as next best thing to do, use steel, or composite or what not?	Has the application of screw or square spikes any effect on crushing?	Relation of kinds of ballast to tie-crushing.	Relation of character of sub-grade to tie crushing.
)	No. We have difficulty in getting ties of our present standard cross-section, i. e., 7 in. by 8 in.	Not ready to answer.	No.....	If all ties are equally tamped, so that support is the same, kind of ballast does not affect crushing.	No relation, provided ties are equally tamped.
1	No.....	Would recommend some form of steel tie having wood insets for rail-bearing surface, wood insets to be deep enough to hold screw spikes.	Screw spikes decrease the crushing, as they do not work out of place as readily as square spikes. They hold the rail down against the tie and eliminate much of the impact.	Less crushing on ash ballast than on stone and the former is preferable on roads of light tonnage. On roads of heavy tonnage the additional tamping required on ash ballast would more than offset the increased crushing if stone ballast were used, so far as life of tie is concerned.	More crushing on rigid sub-grade, except where sub-grade is so soft that track is in poor surface most of the time.
2	I think not..... ...	Use tie-plates not less than § in. thick and 10 in. long to cover entire face. Use preservative process on all timber in track and steel or composite ties where conditions make their use economical.	Experience not sufficient to give definite answer.	The more unyielding the bed the sooner the ties crush. Therefore, ties crush earlier in stone than in any other kind of ballast.	.....
	No.....	Treat ties and prevent destruction from wear by use of properly designed tie-plates of sufficient area and proper fastenings.	No.....	.....	.....
4	Having traveled over the timber country which now supplies the cross-ties of this section of the country, it is my opinion that any demand for larger sectional area of ties cannot be granted. A standard tie at the present time is practically 7 in. thick by 8 in. face. A very few ties of larger area can be secured.	This is a difficult question to answer, unless one has had a long experience in the use of steel and composite ties. At the present time the P. & L. E. R. R. Co. is experimenting with both steel and composite cross-ties. Steel cross-ties have been in use four years. Composite ties have been under test during a similar period, but not one design has continued in use for this length of time. All experience shows that any opinion respecting the merits of steel and composite ties is more or less worthless, unless based on an experience of a minimum of 10 years. It is practically certain that the railroad will be forced to use other than wooden ties in the future, and good judgment requires that the railroads begin at once to experiment with both steel and composite cross-ties. I am satisfied that both of these forms will be largely used in the future, but would not hazard a definite opinion at the present time. More experience is necessary in order to develop the data which should form the basis of an opinion.	No experience. We think not.	We have not noticed any crushing of white oak ties.	See No. 10.....

EXHIBIT F—Continued.

Line No.	8a With the increased consumption and the decreased available supply, can the demand for large sectional area of ties be met?	8b If a large sectional area of tie is not available, what would you recommend as next best thing to do, use steel, or composite or what not?	9 Has the application of screw or square spikes any effect on crushing?	10 Relation of kinds of ballast to tie crushing.	11 Relation of character of sub-grade to tie crushing.
35	Yes.....	Not enough experience.	No experience with screw spikes. Every time a spike is driven into a tie it cuts fiber, weakens the tie and must affect crushing.	Have no data on this or further questions.	.....
36	In my judgment, no. .	Would recommend reinforced concrete, provided they have a proper wood cushion.	No experience.....	The more rigid the ballast, the greater the tie-crushing.	The more rigid the sub-grade, the greater the crushing, depending on the ballast.
37	Probably a local question not serious on West Coast.	When ties cannot be had of 6 in. x 8 in. cross-section re-inforced, concrete or steel ties will probably have to be used. By using large tie-plates and preservative treatment, 6 in. x 8 in. timber ties can be made to answer.	Screw spikes lessen crushing effect.	Elastic ballast, such as gravel or zinc tailings, should lessen crushing.	Well-drained, solid sub-grade should lessen
38	Do not think so.....	Use steel ties.....	Have not used screw spikes.	Ties crush worse in soft, yielding ballast that permits "working" of the ties, or very hard, coarse ballast that is unyielding. Good stone or gravel of uniform character, elastic without being mobile, is best to prevent tie-crushing.	Same as ballast, very soft or very hard sub grade is worse for crushing than medium.
39	Improbable.....	Use of wood preservative and tie-plates should be satisfactory for some years, then develop a steel tie.	Square spikes effect not severe especially with tie-plates.	Probably more marked in stone ballast.	Soft roadbed or badly surfaced track increase tie-crushing.

Line No.	12 Relation of axle load to tie-crushing.	13 Relation of frequency of maximum axle load, as applied to a tie, to tie-crushing.	14 Relation of maximum axle load to weight of rail and consequent tie crushing.	15 Relation of impact at joints to tie-crushing.	16 Relation of size of tie plates to crushing o ties.
1	The greater the axle load the greater the crushing. Usually the greater the axle the greater the speed. Therefore, increased axle load increases crushing in greater proportion than direct increase in loading.	Frequency of maximum axle loads affects life of ties so far as failure by crushing is concerned.	Stiffness of rail varies about as square of its weight. If rail is not increased to proper size for maximum load, tie cutting will increase.	Impact at joints causes increased cutting of joint ties.	Tie-plates should be o sufficient size to kee unit crushing force wel within limits of crushin resistance of the ties Any smaller plate tha this will result in ex cessive crushing.
1a	Increase in proportion directly as the weight increases.	The greater the traffic the quicker the ties will crush.	Maximum axle load has tendency to increase crushing in direct proportion to rail tested.	No data, but believe if joints be kept in perfect service that ties will have less tendency to crush than if allowed to remain in improper surface.	Face of tie covered by tie-plate will give greate resistance against an decreases directly i proportion as size of tie plate decreases.

Line No.	12 Relation of axle load to tie-crushing.	13 Relation of frequency of maximum axle load, as applied to a tie, to tie-crushing.	14 Relation of maximum axle load to weight of rail and consequent tie-crushing.	15 Relation of impact at joints to tie-crushing.	16 Relation of size of tie-plates to crushing of ties.
2	Increasing axle loads necessitates more equitable distribution of loading to avoid crushing of ties.	This is interdependent with rail and track structure. Actual relation not known.	This is interdependent with tie and track structure. Actual relation not known.	The increased impact at joints is responsible for increase in tie-crushing.	The tie-plates of greater area and thickness reduce the tendency to crushing.
5	Believe the crushing of ties is greater with heavy axle loading.	Believe the crushing would be greater with frequency of maximum axle load.	The heavier rail would lessen the crushing effect under the maximum axle load.	The greater impact of high speed, compared with slow speed, would, I believe, increase the tendency to crush. This is probably increased at the joints, since they are naturally tamped to a rigid foundation more often than other ties.	Believe there would be no great difference in the amount of crushing with tie-plates of an area equal to the bearing which the rail would have without a plate. To obtain proper value from tie-plates, so far as the crushing is concerned, they should be of greater area than the natural rail contact.
7	Crushing increases with load.	Proportional.....	Proportional as to load in inverse proportion as to rail.	Crushing increases with impact.	Crushing decreases with larger tie-plates, which should distribute load over full face of tie.
8	Increased axle load and frequency of trains increases the crushing of tie. This also applies to your questions 13 and 14, but the weight of rail, tie-plates and ballast are all a factor in the matter; that is, with heavier rail and tie-plates and ballast the tendency of crushing is very much reduced.	....	.....	Crushing of ties at joints far exceeds that at any other part of the rail, but with heavier rail, etc., suggested above, the crushing is lessened.	I am unable to say what the size of tie-plates should be to the crushing of ties. This factor is also controlled by the weight of rail. Our present practice is to use a tie-plate which affords a bearing surface of nearly double that of the rail on the tie. These tie-plates are the same size for 70, 80 and 100 lb. rail, but the crushing surface under the 100-lb. rail is less than under the lighter rail, as the stresses are distributed over more ties.
9	Directly proportional.	Proportional.....	.....	.....	.....
0	Increase of axle load has direct effect in increasing the crushing of the ties in direct proportion to the load.	Direct proportion as above.	In proportion to the space over which the load is distributed by the rail, treating the rail as a girder.	The crushing is increased at the receiving end of the rail.	Nearly in direct proportion, when the tie-plates are of sufficient strength to equally distribute the load.
1	Would say axle load and stiffness and width of flange of rail were much more closely related than axle load and tie.	Undoubtedly frequency of axle load with a fixed rail section bears an important part in the matter of tie-crushing.	Maximum axle load is directly related to weight of rail or vice versa.	Wheel blow on rail end at joint certainly must have some effect on crushing of joint ties.	Somewhat depends upon type of plate and kind of wood.
2	Would expect crushing to increase with the load.	Would expect crushing to bear a fairly distinct relation to the frequency of the application.	Deep, heavy rails, distributing the load over more ties, would naturally decrease the crushing.	The greater the impact, the greater the crushing.	The larger the plate the less the crushing.
3	No records.....	No records.....	No records.....	No records.....	The greater the bearing surface, the lesser the crushing.

Line No.	12 Relation of axle load to tie-crushing.	13 Relation of frequency of maximum axle load, as applied to a tie, to tie-crushing.	14 Relation of maximum axle load to weight of rail and consequent tie-crushing.	15 Relation of impact at joints to tie-crushing.	16 Relation of size of tie-plates to crushing of ties.
14	This has important bearing on tie-crushing. The more weight concentrated at one point the greater the crushing.	This varies in direct proportion.	Heavier the rail over more ties is the weight distributed and consequently crushing is reduced.	Impact at joints very hard on ties, causing them to crush rapidly in case joint is not tight and in good condition.	Plates should be as wide as face of tie and four inches longer than width of base of rail. Size of plate has much to do with crushing.
15	When speed of trains is same, tie-crushing should increase some in proportion to axle load.	Quite frequent.....	.....	Will increase crushing very much.	When tie-plates are not of sufficient bearing area, they tend to increase crushing of ties.
16	Tie-crushing increases with axle load.	The increasing the number of maximum axle loads increases the crushing.	The crushing caused by maximum axle loads is reduced by increasing weight of rail.	The greater impact the more crushing of joint ties will occur.	Large tie-plates will reduce crushing.
17	The heavier the load the sooner the ties will crush.	The more frequently the load is applied, the more rapid the effect.	Use as stiff a rail as practicable and spread load over as many ties as practicable thereby.	If joints of insufficient strength are used, or they wear out under the head of the rail, or bolts are allowed to run loose, the sooner the ties will pound out.	Use tie-plates practically full width of face of tie and as long only as the strength of the plate will allow, without danger of buckling under the rail.
18	See No. 10.....	No effect except when maximum axle load applied exceeds elastic limit in compression.	See No. 10 and No. 13.	See No. 10 and No. 13.	Crushing varies inversely as the area of tie-plates and its resistance to deformation.
19	Crushing effect varies directly with weight.	Crushing effect varies directly with the number of applications.	Same as of No. 12, of course modified by stiffness of rail.	Directly as the force of the impact.	Diminishes as area of plate increases.
20	Think it greater under heavy axle load. Have no exact data.	Think it greater the more frequently maximum axle load is applied. Have no exact data.	Greater axle load requires heavier rail to prevent increased crushing both on account of wave motion and unit stresses, but have no data as to proportion.	No data.....	There is a very pronounced relation which seems to be that crushing diminishes with increase in size of plate up to point where plate buckles or becomes as wide as the tie.
22	Cannot answer.....	Cannot answer.....	Cannot answer.....	Cannot answer.....	Cannot answer. Would favor larger plates as it seems to better prevent crushing and cutting the ties.
24	The heavier the axle load the quicker the crushing.	The greater tonnage with heavy axle load, of course, will permit a shorter life and develop crushing.	If the weight of the rail is lighter than the axle load, the greater the motion which affects the life of tie. Tie-plates should not be less than 7 in. or more than 8 in. wide and should be so made as to make it a part of the tie and not the rail. They should be of such length as to prevent them from cutting in, buckling or allowing rail to roll out, depending on traffic which passes over same.	....	.....

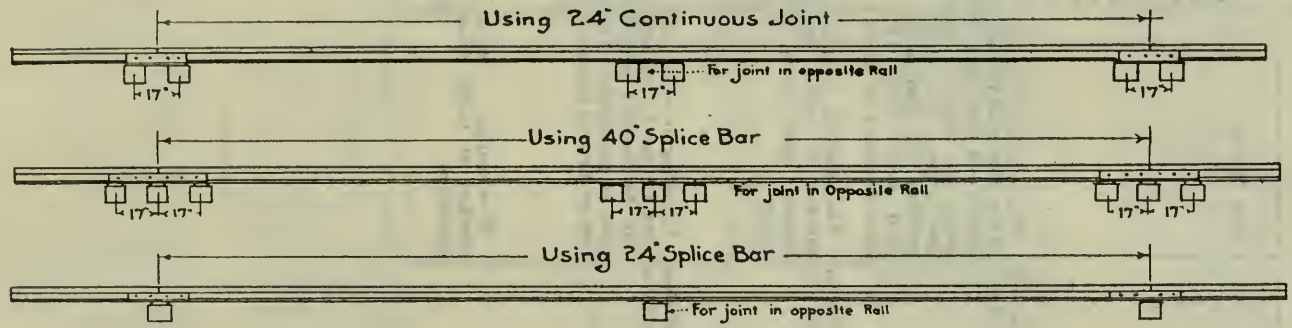
Line No.	12 Relation of axle load to tie-crushing.	13 Relation of frequency of maximum axle load, as applied to a tie, to tie-crushing.	14 Relation of maximum axle load to weight of rail and consequent tie-crushing.	15 Relation of impact at joints to tie-crushing.	16 Relation of size of tie-plates to crushing of ties.
25	With the same weight of rail I believe the tie-crushing is directly proportional to the axle load.	Unless the maximum load is applied very rarely, I should expect the tie-crushing to be directly proportional to the frequency of the maximum load application.	Under the same maximum load the crushing should be less as the weight of the rail increases.	Tie-crushing, I believe, is directly proportionate to the amount of impact at the joints.	A large, stiff tie-plate would undoubtedly reduce the tie-crushing to a minimum.
27	Tie cutting, we think, is proportional to axle load and density of traffic, but reduced by tie-plates.	Our minimum axle load on coal, coke and ore trains is 43,000 lbs., maximum 60,000 lbs., empty cars, 10,000 lbs. We have not been able to observe differences, except as to frequency of loads.	The N. & W. Ry. is generally equipped with 85-lb. A. S. C. E. rail which has given good service under above loads; but we expect better results with the use of 100-lb. A.R.A. "B" type rail, purchased since 1910.	We have secured good results by the general use of a rigid joint; our standard is the Bonzano. With ties spaced as above, we have not observed more rapid wear on joint ties than intermediate.	We think this is substantially proportional.
28	.....	.....	Less crushing with heavier weight of rails.	.....	Less crushing with increased width of plate.
29	Tie-crushing varies directly with axle load.	Tie-crushing increases with frequency of application.	The heavier, and therefore stiffer, the rail in proportion to maximum load, the greater the distance over which the rail will distribute its load. The more ties the axle load is carried by, the less the tie-crushing.	The effect of impact at joints is equivalent to increasing static axle loads, and will increase tie-crushing. Crushing will be greater with supported joints than with suspended joints.	To reduce crushing to a minimum, tie-plates should be full width of tie and project beyond base of rail as far as depth of tie-plate will distribute the load. Non-uniformity in tamping ties has considerable effect upon the crushing. A well-tamped tie adjacent to too loosely tamped ties in a very rigid roadbed will get the maximum crushing.
30	Tie-crushing probably increases in direct proportion to increase of axle loads.	Tie-crushing probably increases in a greater proportion than frequency of application of load. That is, if the frequency of application is doubled, crushing is more than doubled. Exact relation impossible of statement.	Weight of rail is, of course, factor of importance. As weight (and height) of rail increases, distribution of load increases; hence tendency of tie to crush decreases.	Impact at joint naturally increases amount of crushing.	Crushing decreases as size of tie-plates increases.
31	Crushing is less where axle load is less. Flat wheels naturally do much more damage under heavy load than where load is light.	Frequency has very little effect except in the case of load over flat wheels. The higher the speed of trains, the greater the impact from flat wheels.	Crushing effect increases directly with the maximum axle load and the base area of road should vary proportionately. The weight of rail has not kept pace with the increase in axle load.	The crushing at joint ties is from 50 per cent. to 75 per cent. more than at intermediate ties. This increases to about 200 per cent. after the ties are in track five or six years.	Tie-plates should be made as wide as the ties and extend not more than 3 in. outside the rail. Tie-plates greatly decrease the crushing. In fact, a tie-plate designed as above would practically prevent crushing altogether.
33	.....	.....	.....	.....	Plates should be large enough to prevent crushing.

12	13	14	15	16
Relation of axle load to tie-crushing.	Relation of frequency of maximum axle load, as applied to a tie, to tie-crushing.	Relation of maximum axle load to weight of rail and consequent tie-crushing.	Relation of impact at joints to tie-crushing.	Relation of size of tie-plates to crushing of ties.
See No. 10.....	See No. 10.....	See No. 10.....	See No. 10.....	The P. & L. E. R. R. Co. is now using tie-plates with an area of about 72 sq. ins. White oak ties are also used. Tie-plates are joined to the ties with screw spikes. This area seems to be the minimum required for effectiveness.
The greater the axle load the greater the tie crushing; depends also on character of ballast and sub-grade.	The greater the frequency of maximum load, the more rapid the tie-crushing.	The heavier the rail the less the tie crushes.	The effect of impact at the joint would depend largely on the kind of angle bar used. The bar giving the most uniform distribution of load would have the least tendency to crush.	The greater the area and thickness of the tie-plate the less the crushing of the tie.
Practically directly in proportion to axle loading.	Same as No. 12.....	Weight of rail must be increased to meet increased axle load.	Tie crushing is most marked at joints and depends upon upkeep of joints.	Tie-plates should be increased to meet increased loads. They should be practically same width as tie, and increased in length as axle loads are greater.
The heavier the axle load the greater the crushing tendency in an increasing ratio; after passing limit of elasticity in ballast and sub-grade entire increment of axle load tends to crushing.	Crushing increases with frequency, but in small ratio.	Heavy rail distributes axle load and reduces tie-crushing.	Crushing is worse at joint tie due to impact, but the nearer a perfect joint be approached the less such effect becomes.	Crushing is worse with small plates; also worse with thin plates which spring under maximum load and tend to "work" on ties.
No data at hand. Observation shows decided crushing.	No data at hand. Tie-crushing probably not far from direct proportion.	.....	Tie-crushing more marked at joints than elsewhere.	Increase in thickness of plates has materially lessened tie-crushing.

EXHIBIT F-1.

ARRANGEMENT OF TIES UNDER JOINTS

B-54



Splices	24" Continuous Joints										40" for 100 lb. Rail & 24" for 80 lb. Rail															
Ties	7"x 9"x 8'-6" Ties										7"x 9"x 8'-6" Ties										7"x 8"x 8'-6" and 6"x 8"x 8'-0" Ties					
Length of Rail	33'		30'		28'		26'		24'		33'		30'		28'		26'		24'		33'	30'	28'	26'	24'	
Weight of Rail	100	80	100	80	100	80	100	80	100	80	100	80	100	80	100	80	100	80	100	80		80		80		80		80
Ties per Rail	20	20	18	18	16	16	16	16	14	14	20	19	18	18	18	16	16	15	16	14		22		20		18		17		16
Center Bet. Ties.	20 1/8	20 1/4	20 3/8	20 3/8	21 1/2	21 1/2	19 3/4	19 3/4	21 1/4	21 1/4	20 1/4	20 7/8	20 7/8	20	19 1/8	21	20 5/16	20 5/16	18 5/16	20 5/16		18		18		18 11/16		18 3/4		18
Ties per Mile	3200	3200	3168	3168	3017	3017	3249	3249	3080	3080	3200	3040	3168	3168	3394	3017	3249	3046	3520	3080		3520		3520		3394		3452		3520

NOTE:-
Ties to be laid heart side down
On single track ties to be lined to center line of track
On double track ties to be lined on outside ends
On four track ties for 2 middle tracks to be lined on outside ends and ties on outside tracks to be lined on outside ends

APPROVED
Asst. Chief Engineer

Rev. 7-9-'10.

L.S.&M.S.Ry | Engr. Dept. | S. Rockwell C.E.

STANDARD
TIE SPACING

No Scale | Aug. 31-1906 | 18897-19-D-9-B

CONCLUSIONS.

So far as your Committee is able to determine it is not feasible to lay down any fixed rule for the size and spacing of ties based on the A, B and C classification of density of traffic, for the following reasons, each of which in itself has a certain definite restriction, as well as an interrelation with all others, viz.:

(1) Character of subgrade varies radically on the same road and in different parts of the country.

(2) Kind of ballast varies widely.

(3) Necessary depth of ballast varies with weight of axle loads, as well as density of traffic.

(4) Necessary distance between face of ties varies with weight of axle load, as well as density of traffic.

(5) Kinds of timber used for ties vary in different sections of the country.

(6) Width of base of rail (or weight of rail) and use of tie-plates.

(7) Treated or untreated ties, crushing stress and durability.

(8) Amount of labor spent on track maintenance.

(9) Drainage.

However, in general it may be considered good practice for Class A and perhaps B roads to space ties 10-in. to 12-in. face to face; the width of tie is not so important if 10-in. to 12-in. spacing face to face is followed; provided, however, the minimum width of face of tie is limited to 7 in.

(2) TIE RENEWALS IN CONTINUOUS STRETCHES VERSUS SINGLE TIE RENEWALS.

The Sub-Committee appointed to investigate the comparative merits of "Tie renewals in continuous stretches versus single tie renewals" issued the following letter to the heads of the proper departments of the principal railroads operating in the United States and Canada:

"It is desired to obtain information as to the comparative merits of "Tie renewals in continuous stretches versus single tie renewals." Will you kindly give us your practice and opinion in reply to the following questions:

"(1) What is the practice of your road in renewing ties; tie renewals in continuous stretches or single tie renewals?

"(2) Do you think it advisable to renew ties in continuous stretches?

"(3) What would be the advantage of this latter method of tie renewals?

"(4) What are the advantages or disadvantages of single tie renewals?

"(5) Which practice would you recommend?"

Fifty of these letters were sent out and 35 replies were received. It is noted that all who replied gave the subject the most careful attention, and thereby furnished the Committee with some valuable information. The replies as received from the various railroads are as follows:

Mr. George W. Kittredge, Chief Engineer, New York Central & Hudson River Railroad:

1. The practice of our road is to renew ties under the method termed "single tie renewals."

2. No.

3. There are no advantages in renewing ties in continuous stretches, except that possibly for the first year or two you might get better track than by renewing singly.

4. The advantages of single tie renewals far outweigh the disadvantages; in fact, I know of no disadvantages. The advantages are:

(1) You are able to let a single tie remain in the track until entirely worn out, since it has the advantage of the ties on each side of it being sound.

(2) The track is always kept safe by having a large proportion of good and comparatively new ties in the track. With continuous renewals there comes a time when, even before the ties are entirely worn out, the track is not safe, and, in order to maintain safety, it is necessary to take the ties out of track before they would, under other conditions, need to be removed, thus shortening their lives.

5. Unhesitatingly I recommend the practice of single tie renewals.

Mr. F. S. Stevens, Engineer Maintenance of Way, Philadelphia & Reading:

1. The practice of our road is to "spot in" or renew only such ties as will not do their work another year on account of being too soft to carry the load.

2. Yes, if the track where ties are to be renewed can be taken out of service while work is being done.

3. Advantages of this method are: That by doing this work without interruption, the labor costs less, by removing the ballast to subgrade and forking it back, dirt is removed and good drainage restored. By retamping on fresh ballast the greatest of trouble is removed; i. e., the constant care of looking after and retamping "spotted in" ties for about 2 years after being placed in track.

4. The sole advantage of "spotting in" ties where track can be taken out of service while renewals are being made, is that when ties have been taken out of track they are very liable to be wasted or destroyed prematurely. If track cannot be taken out of service to permit tie renewals without interruption, the increased cost of labor to renew "out of face" makes this method prohibitive. Therefore, under these conditions the "spotting in" method is most economical. As far as consistent with economy, ties should then be renewed in pairs, as labor costs nearly as much to renew one tie as two. In any event, ballast should be renewed at same time with ties, as this will make good drainage. This is important, for, unless air can reach the under side of ties, water will, and then trouble begins in earnest.

5. Under the conditions which we generally have to work I recommend the practice of "spotting in." However, when conditions permit I would renew ties "out of face" and would place every tie which will render further service in some track where its remaining life will be used to best advantage.

Mr. C. S. Millard, Engineer Track and Roadway, Cleveland, Cincinnati, Chicago & St. Louis Railway:

1. Single tie renewals.

2. Not unless all ties in continuous stretches are all worn out.

3. We can see no advantage of renewing in continuous stretches, as under the long run the waste of tie timber would be prohibitive.

4. Advantage of single tie renewal is that you avoid any waste of tie timber and by that method track is kept in a continuously safe condition.

5. Single tie renewals.

Mr. Samuel Rockwell, Chief Engineer, Lake Shore & Michigan Southern Railway:

1. We ordinarily renew ties singly.

2. We do not, as a rule, renew ties in continuous stretches.

3. I know of no advantage except that it would probably afford a better record of the life of the ties.

4. Advantage of single tie renewal is that only such ties as need to be renewed are renewed; whereas, "out of face" renewal many ties which would last longer are taken out and thrown away.

5. I would recommend taking out only such ties as need to be taken out.

Mr. E. J. Correll, Engineer Maintenance of Way, Missouri Pacific Railway:

1. Single tie renewals.

2. No.

3. I know of none. Would consider it a disadvantage.

4. Disturbs the surface less, is more economical and makes condition of track more uniform.

5. Single tie renewals.

Mr. R. Trimble, Chief Engineer Maintenance of Way, Northwest System, Pennsylvania Lines:

1. The practice of our road is to renew only such ties as will not last another year. This, I take it, is what is termed "single tie renewal."

2. No. By doing so the life of the tie is considerably shortened. It is known that a tie when left in place will last longer than if taken out, thrown around, loaded and unloaded, and then put in somewhere else. The chances are that many ties which would last another year or two if left in their place, would be wasted and not used elsewhere.

3. I know of no advantages of renewing ties in continuous stretches that would even compensate for the disadvantages.

4. Advantage of single tie renewals is the resultant economy. I know of no disadvantage.

5. I recommend single tie renewals.

Mr. C. W. Johns, Engineer Maintenance of Way, Chesapeake & Ohio Railway:

1. Until recent years it has been the practice of this road to renew ties in continuous stretches. For the past 2 or 3 years we have tried to get all of our section foremen on double track to work one track one year and the other track the next, putting in single ties where required. On single track the foremen work half the section one year and the other half the next, putting in single ties where required.

2. No. This method necessarily allows a portion of the track to become unsafe before the ties are renewed; at least, the ties get so soft it is impossible to maintain good surface, while by slipping in single ties this condition does not exist and there are always sufficient sound ties under each rail to maintain proper surface and gage.

3. I know of no advantage of renewing in continuous stretches.

4. Advantage of this method is that you never have any stretches of rotten or unsound ties and there are always enough sound ties to maintain proper surface and gage.

5. I prefer the single tie renewals.

Mr. J. B. Berry, Chief Engineer, Rock Island Lines:

1. Single tie renewals.

2. Not unless they are all decayed or worn out so that they need to come out at the same time.

3. I know of none.

4. I believe the economy of a railroad demands that no tie should be taken out until decayed or worn out. The men along the line are educated to better rules of economy by adopting such methods, and you never can keep all ties, even if you lay them in a continuous stretch, in the same condition so that they should all be taken out at the same time.

5. I favor only taking ties out as stated above.

Mr. William Twining, Engineer Maintenance of Way, Central Railroad of New Jersey:

1. On this division where slag and engine cinders are used for ballast, it is the practice to renew ties singly.

2. Do not think it advisable to renew in continuous stretches.

3. One advantage of renewing in continuous stretches would be that it avoids, in a measure, frequent disturbance to the ballast bed as well as the line and surface.

4. The advantage of single renewal is that greater average life of the tie is thereby secured.

5. In stone or heavy slag ballast, and under heavy traffic, close renewal or practically entire renewal is recommended. In light slag or cinder ballast, under ordinary traffic, single renewal is recommended.

Mr. L. R. Zollinger, Engineer Maintenance of Way, Pennsylvania Railroad:

1. Single tie renewals—method known as "spotting."
2. By no means.
3. There is no advantage.
4. Advantage of single tie renewal is economy, permitting of ties remaining in that are too good to come out, based on the knowledge that all material is not the same and does not have the same lasting qualities, and permits of removal of those ties, the lives of which are not up to the average, when they become unfit for use.
5. We recommend the practice of "spotting."

Mr. H. S. Wilgus, Engineer Maintenance of Way, Pittsburg, Shawmut & Northern:

1. It is our practice to make single tie renewals.
2. Do not think it advisable to renew in continuous stretches, except in difficult places.
3. Advantage of renewing in continuous stretches is less frequency of disturbing roadbed.
4. Advantages of single renewal is getting full value out of all ties. Disadvantage is in covering greater distance of track and disturbing more roadbed.
5. Would recommend single tie renewals as being the most economical.

Mr. John R. Leighty, Engineer Maintenance of Way, Missouri Pacific Railway:

1. Single ties as needed.
2. No.
3. Better track than average, once in about 6 or 7 years.
4. Track kept in uniform condition at all times and ties renewed only when they need to be, instead of before or afterward.
5. I would recommend single tie renewals.

Mr. J. R. W. Davis, Engineer Maintenance of Way, Great Northern Railway:

1. It is the practice of our company to renew ties singly or in groups of 2, 3 or 4 at a time as their condition may make it necessary.
2. We do not think it advisable to renew in continuous stretches.
3. I doubt there being any advantage in continuous tie renewals.
4. Disadvantage of single tie renewals are yearly disturbances of track, greater labor cost of distributing and placing ties. Advantage is a stronger track year for year and less waste of material.
5. We recommend single tie renewals.

Mr. P. C. Newbegin, Maintenance Engineer, Bangor & Aroostook Railroad:

1. It is our practice to renew ties singly.
2. Do not think it advisable to renew ties in continuous stretches, except in locations where paving or other covering must be removed to reach the ties, and, possibly, on short stretches of track which are under exceptionally heavy traffic.
3. Advantage of renewing in continuous stretches is that it lessens

the labor cost per tie and disturbs the roadbed less frequently than must be done where ties are removed singly.

4. Advantage of single renewal is that full life of ties can be utilized, and no ties need be removed until they are worn out. This in all but exceptional cases would more than balance the saving of cost from removing in continuous stretches and the disadvantage of more frequent disturbing of the roadbed.

5. Except in rare cases I would recommend single tie renewals.

Mr. J. M. R. Fairbairn, Assistant Chief Engineer Eastern Lines, Canadian Pacific Railway:

1. It is our practice to make tie renewals only as they require it.

2. Would not consider it economy to renew in continuous stretches and see no advantage gained by this method. It is our practice in the spring of each year to send a man, well versed in tie conditions, over each sub-division, and he marks with paint the ties he considers not good for another year's service, using proper judgment and taking into consideration condition of adjoining ties. These are replaced during the summer season and if a section foreman considers that a tie has not been marked which, in his opinion, should be replaced, he takes matter up with the Roadmaster, who decides whether or not renewal will take place.

3. Only advantage is that it entails less work.

4. Advantages of single tie renewals are that only those ties are removed which have served their life. In the other case ties are removed which have another year or two of service in them, so that in renewing in continuous stretches, there is, therefore, more waste.

5. I, of course, recommend the single tie renewal system.

Mr. S. A. Jordan, Engineer Maintenance of Way, Baltimore & Ohio Railroad:

1. Our practice is to renew only those ties that will not last another year.

2. No. Our ties are inspected every spring by a regular Tie Inspector, who marks all ties that are to come out.

3. Do not think there is any particular advantage.

4. Believe that renewals as made by the B. & O. are better than in continuous stretches. By taking out only such ties as will not last another year you get a uniform amount of good timber under your rail.

5. I recommend renewing ties singly.

Mr. W. C. Cushing, Chief Engineer Maintenance of Way, Southwest System, Pennsylvania Lines:

1. The practice of our Lines is to renew ties as worn out or decayed, and not in continuous stretches.

2. No, except, possibly, between station platforms or in street crossings where the labor of getting at the ties is great.

3. I believe the following advantages might be claimed for the method of renewing in continuous stretches: (1) Track could be given uniform lift, and, when new ties were in place, uniform support would be furnished them; (2) Cost of laying in continuous stretches would probably be less than laying them singly.

4. Advantages of single tie renewals are: (1) The track, as a whole, is kept in a more uniform condition, as to the quality of the supporting ties; (2) Only ties that should be removed, account of wear or decay, need be removed. Disadvantages of this method are: (1) The old bed of the tie must be dug up to get the new tie in place, or entire track given sufficient raise to accomplish this result; (2) Where platforms, planking or interlocking fixtures must be disturbed to remove ties, this

disturbance takes place oftener under the single tie renewal system; (3) The cost of renewal per tie is probably somewhat higher under this system also.

5. We would recommend the renewal of ties singly. Because: (1) The general safe condition of the track is greater; (2) The average life of the ties, we believe, will be lengthened by the single tie renewal method, as, when renewing in continuous stretches, many ties are necessarily taken out and lost which might safely be left in the track a year or two longer if the adjoining ties were good.

Mr. Geo. B. Woodworth, Inspector of Rail, Chicago, Milwaukee & St. Paul Railway:

1. The practice of our road is to make single tie renewals.

2. From a financial standpoint I do not think it advisable to renew ties in continuous stretches, since the life of the ties is variable and the usable ties taken out deteriorate rapidly, and will lose 25 to 50 per cent. of their usefulness before they can be used again. In special cases it is more advantageous from every point of view to renew in continuous stretches, as in tunnels, narrow rock cuts or over very busy stretches of track where the track can be given over for a short time to a large force of men.

3. Advantage of renewing in continuous stretches is, that after the ties are placed, roadbed will not again be disturbed for a long time, and a better general condition of track can be maintained.

4. Above answer also covers your third question.

5. As a general proposition I should recommend single tie renewals.

Mr. M. C. Hamilton, Engineer Maintenance of Way, New York, New Haven & Hartford Railroad:

1. It is our practice to renew ties singly.

2. This depends on the local conditions; on four-track sections interior tracks, or adjacent to station platforms, the renewing of ties "out of face" is considered the economical practice.

3. We do not consider the renewal of ties "out of face" the economical practice under normal conditions.

4. Advantages of single tie renewals are greater economy and more uniform condition of track.

5. I would recommend the renewing of ties singly, except where unusual conditions demand the other method.

Mr. C. M. James, Engineer Roadway, Atlantic Coast Line:

1. The practice of our road is single tie renewals.

2. Under the conditions existing in this territory, I do not think it advisable to renew in continuous stretches.

3. The advantage of the above method is in the saving of labor, but this advantage is outweighed by the disadvantage that material is used.

4. Advantage of single tie renewals is in the fact that full life can then be gotten from each individual tie.

5. There is no question in my mind but that single tie renewals is the better practice.

Mr. G. J. Ray, Chief Engineer, Delaware, Lackawanna & Western Railroad:

1. Single tie renewals is the method practiced as much as possible. We find that some of our old foremen have been in the habit of renewing ties in continuous stretches, and it is hard to break them of this practice, and there are cases where we permit this method of renewal through

station grounds where it is more difficult to get at the track, making use of the better ties taken out for sidetrack purposes.

2. No. If all the ties are in such shape that they should come out, I do not think the track is in first class shape, and am not an advocate of permitting track to get in such shape that all ties can consistently be taken out at the same time.

3. Only advantage is that more ties can be placed at the same cost.

4. Full life of service can be gotten out of every tie, and this advantage of single tie renewal will more than outweigh any advantage in favor of the former system.

5. Single tie renewals.

Mr. W. L. Breckinridge, Engineer Maintenance of Way, Chicago, Burlington & Quincy Railroad:

1. We practice the system known as "single tie renewals."

2. No, except in special cases.

3. Only advantage I know of in renewing in continuous stretches is in cases where the life of the rail under heavy traffic about equals the life of the ties; that is, in renewing rail where the traffic is heavy, ties should be renewed in full and unless ties under old rail are almost new, they should all come out. You will then have a track which will not have to be disturbed during the life of the new rail on account of tie renewals.

4. Single tie renewals is all right, especially on less important main lines where the life of the rail exceeds that of the tie. We are also able to keep yearly check on our gage and hold track to a more perfect gage, since the average efficiency of a proper single tie renewal track is almost constant, while with a continuous renewal track the holding power of spikes and general efficiency is on the decrease. Disadvantages of single tie renewal are: (1) Frequent disturbance of roadbed; (2) Inability to get a firm and equal bearing on the new ties; (3) Taking up too much time in the Spring for this sort of work when the track needs picking up; (4) Keeping right of way littered each year with new and old ties.

5. I would recommend continuous renewal only when relaying rail on main line heavy traffic road. In such cases the life of the rail does not exceed that of the ties. In all other cases I recommend single tie renewal, as the life of tie timber varies too much to consistently renew in continuous stretches.

Mr. L. G. Curtis, Engineer Maintenance of Way, Baltimore & Ohio Railroad:

1. Our practice is to renew ties singly.

2. No, only under extraordinary conditions.

3. No advantage.

4. The change to single tie renewals gives you sound ties throughout.

5. Would recommend single tie renewals, excepting in rare cases where ties are all poor.

Mr. Alexander Bonnyman, General Manager, Atlanta, Birmingham & Atlantic:

1. Single tie renewals. When a tie shows signs of decay, it is taken out.

2. No, unless traffic is very heavy and the roadbed of such nature as to make continuous renewals necessary.

3. No advantage unless under above conditions.

4. Advantage in single renewals is that full life of every tie is utilized.

5. I would recommend that where the earnings of a road demand economy, ties be renewed singly; where traffic is heavy and the Company is able to renew in continuous stretches, that this be done.

Mr. W. J. Towne, Engineer of Maintenance, Chicago & Northwestern Railway:

1. Tie renewals based upon actual condition of tie, except joint and center ties; these are usually renewed together, and if any ties removed are serviceable elsewhere, they are properly utilized.

2. No, not as a general proposition. In slag or rock ballast I think it economy to renew continuous to the extent that any ties that will not last 2 years or more be taken out.

3. Principal advantage would be in securing more uniform rail bearing and economy when the life of the tie would not offset the labor charge for renewal and less disturbance of track bed result in general economy, in rail, etc., as well as improved roadbed.

4. Advantage of single tie renewals consists wholly in conservation. Disadvantages mentioned in reply "three."

5. Depends on character of line, volume of traffic, ballast, rail and roadbed. In gravel ballast with light traffic would recommend single tie renewals; in rock or slag ballast with heavy traffic would recommend renewal joint and center ties together, and renewal of all ties that would not last 2 years, both as a matter of economy and other reasons before named.

Mr. E. F. Mitchell, Chief Engineer, Missouri Pacific Railway:

1. Single tie renewal is the practice of our road.

2. No, we do not think it advisable.

3. The average life of a tie on this system is 8 years. For the sake of argument assume that the best method of renewing ties in continuous stretches would be to renew all the ties under 1 rail length in a given year at one time. Then about 6 years later it would be necessary to renew at least a portion of these ties, possibly 50 per cent. of them. The balance of ties under this rail would probably last from one to four years.

5. If the ties rotted at the end of 6 years are not "spotted in" or renewed, as called, in single ties, but, instead of this the entire rail length is renewed for the purpose of reducing the cost of labor for renewal per tie, then about one-half the ties under this rail will be renewed when they have from one to four years' service left.

Mr. W. D. Taylor, Chief Engineer, Chicago & Alton Railway:

1. Single tie renewals, except where there are 2 or more consecutive ties to be renewed.

2. Only when renewing in track to be surfaced, as we do not think it advisable to leave old ties in track that is being surfaced, and then have to again disturb the track and ballast the next year to change out the remaining old ties.

3. Advantage of single tie renewals is that fewer tie renewals are required to keep track in good condition where only the worst ties are taken out and new ties put in in this way than would be the case where long stretches of ties are taken out, and the track shaken up and ties knocked around for spacing.

4. and 5. Answered in the above.

Mr. F. R. Layng, Engineer of Track, Bessemer & Lake Erie Railroad:

1. Single tie renewals.

2. No, I do not think it advisable to renew in continuous stretches.

3. The cost of renewals per tie (labor only) would be less when ties are renewed "out of face." This is on account of the fact that only about half as much ballast per tie would have to be dug out to make renewals. Disadvantage: In renewing in stretches, when it is decided that renewals should be made, track is in weakened condition. This being so, chances are either taken to run the ties a little longer, or, if the responsibility rests with a man who is timid, renewals are ordered at a time when most of the ties would last two or three years longer, if not disturbed. Neither of the above conditions tends to good practice. The ideal, to my mind, is to get the longest possible life from a tie, consistent with safety, without disturbing it.

I am quite sure the tendency of the average man would be to remove the ties in ample time so that the result would be to reduce the life per tie to about five years. This would increase the cost of tie renewals from 15 to 20 per cent. Inasmuch as tie renewals make up the largest single item in maintenance expense; most roads would hesitate to increase same unless some very decided advantage resulted therefrom.

Another disadvantage: It is practically impossible to select ties which would decay so uniformly that any great length of track could be renewed without taking out some ties still fit for service. Some use would have to be found for these ties and they would no doubt be used in sidetracks. Assuming the following:

Cost of first-class tie delivered along track	$0.70
Cost of second-class tie delivered along track	.60
Average life of first-class tie in main track	7 years
Average life of second-class tie in siding	7 years
Average life of first-class tie removed from main and used in siding	3 years

We arrive at the figures given below:

Cost of tie removed from main and put in siding 3 years at 10c per year	$0.30
Cost to remove from main track	.03
Cost of putting in siding	.08
Total cost	$0.41
Average cost per year in siding	$0.13 2-3
Cost of second-class ties	$0.60
Cost of putting in siding	.08
Total cost	$0.68
Average cost per year in siding	$0.09 5-7
Cost of first-class tie in siding	$0.70
Cost of putting in siding	.08
Total cost	$0.78
Average cost per year in siding	$0.11 1-7

The above shows clearly, if my assumption is correct, that it does not pay to use same in sidings.

4. Advantages of single tie renewals: (1) Effective life of tie is longer; (2) Average condition of track as to safety is better; (3) Single track renewals disturb roadbed less; (4) Trackmen can arrange work to better advantage in single tie renewals; (5) Cost of tie renewals con-

siderably in favor of single tie practice. (Net cost, including everything connected with this item.)

Disadvantages: I can see no particular disadvantage in the method of renewing ties singly. The most expensive thing we have is labor and least amount of labor per tie is expended.

5. Usual argument against single tie renewals, I presume, is that after making same, track does not ride smoothly or is spotty. Now this is usually the case, but it is the result of poor maintenance and is not a necessary evil which follows the practice of single tie renewal. If the trackmen will properly tamp new ties a week or ten days after they have been put in, this trouble can easily be taken care of.

Mr. F. D. Anthony, Chief Engineer, Quebec, Montreal & Southern Railway:

1. We renew all ties on this road as necessity requires; i. e., when they are decayed, broken or otherwise defective.

2. No.

3, 4 and 5. Tie renewals sometimes occur in continuous stretches, but this, no doubt, comes under your classification as "single" and practically all my experience has been on this line.

Mr. Earl Stimson, Chief Engineer Maintenance of Way, Baltimore & Ohio Railroad:

1. Single tie renewals is the practice of our road.

2. No.

3. Can see no advantage of renewing ties in continuous stretches.

4. Advantage of single renewal is in obtaining extreme life of each individual tie.

5. I would recommend single tie renewals. As a general proposition would not consider continuous tie renewals as having any advantage unless it might be in first-class track in which treated ties of the same class of timber were used, equipped with screw spikes and tie-plates and laid in stone ballast. This is a very unusual occurrence and it is therefore the reason I answer your third question as I do.

Mr. J. E. McNeil, Inspector Roadway and Track, Atchison, Topeka & Santa Fe Coast Line:

1. Our practice is single tie renewals.

2. Not advisable on our line, at least, where there is so much difference in the length of time our ties last.

3. There would be no advantage on western lines.

4. We find that the life of tie timber received at the same time and cut in the same forest varies from one to five years. To make tie renewals in continuous stretches, would, we think, be extravagant. At one time in the Middle West where we got eight years' service out of our white oak ties, and the inspection was such as to have them about the same in quality, we figured on renewing about one-eighth of the number each year. In this way the work could be done with a small extra gang.

5. In this part of the country where we have such a variety of tie timber and their lasting quality is so different, I would recommend single tie renewals.

Mr. S. M. Braden, General Superintendent, Chicago & Northwestern Railway:

1. We make tie renewals as needed—very seldom, however, in continuous stretches.

2. No, as conditions necessitating continuous renewals would, in our opinion, indicate improper previous maintenance.

3. Can see no advantage. Increased maintenance expense would be a disadvantage.

4. Principal advantage in single renewal is less expense, and, in addition, there is less disturbance as to surface of track.

5. We would recommend the method of single tie renewals.

Mr. J. K. Howard, Engineer Maintenance of Way, Ann Arbor Railroad:

1. Single tie renewals. We take out no ties which will last another year.

2. Do not think it advisable to renew in continuous stretches.

3. No advantage in above method.

4. Advantage of single renewal is that only ties unfit for another year's service are removed and I would call this the more economical practice.

5. I recommend single tie renewals.

Mr. G. B. Owen, Engineer Maintenance of Way, Erie Railroad:

1. The practice of this road is to renew ties singly.

2. Do not think it advisable to renew ties in continuous stretches.

3. I cannot name any advantage of renewing ties in continuous stretches.

4. The advantage of single tie renewal is economy and uniformity in maintenance, and uniformity of track conditions as well as maintenance charges.

5. I would recommend an inspection by a competent inspector of the old ties in the track before renewal, and that only such ties be removed which would not give one additional year's service from the time the inspection was made. This practice, if continued from year to year, will result in a stronger condition of the roadbed with the employment of a less number of men per section than would be necessary where continuous renewals were made. It would also materially assist the purchasing department in the placing of their contracts for ties. The disadvantages which developed from our tests in continuous tie renewals were that a large number of ties were removed which would give one, two, three or four years' further service. An effort was made to utilize these ties in other tracks, but it is manifestly a great loss of labor to remove a tie until it has worn out and then attempt to again replace it in the track. A further disadvantage resulted in an effort to reduce the forces on sections where continuous tie renewals were made in order to make up, in a way, the excessive cost of these renewals. In a very short time this reduction resulted in bad surface and line so that in the end there was really no saving in labor.

From the excellent information received it is evident that the general practice is to renew ties singly, except in unusual cases at station platforms, highway crossings, narrow tunnels or interlocking plants where it requires much labor to get at the ties or to uncover them for the purpose of renewal.

CONCLUSION.

The Committee recommends the practice of single tie renewals.

(3) METAL, COMPOSITE AND CONCRETE TIES.

Your Committee was directed to prepare a report on the use of metal, composite and concrete ties.

During the year the members of the Sub-Committee dealing with this subject held two meetings—one at Pittsburg, September 5, 6 and 7, 1911, at which time an inspection of the following ties was made:

Rohm Steel Tie, Sewickley, Pa., Pennsylvania Lines, Northwest System.

Universal Steel Tie, Emsworth, Pa., Pennsylvania Lines, Northwest System.

Reigler Concrete Tie, Emsworth, Pa., Pennsylvania Lines, Northwest System.

Carnegie Steel Tie, Pittsburg, Pa., Pittsburg & Lake Erie.

Carnegie Steel Tie, McKees Rocks, Pittsburg & Lake Erie.

Universal Steel Tie, Pittsburg, Pittsburg & Lake Erie.

Atwood Steel and Concrete Tie, McKees Rocks, Pittsburg & Lake Erie.

Bruckner Concrete Tie, McKees Rocks, Pittsburg & Lake Erie.

Snyder Steel Tie, Derry, Pa., Pennsylvania Railroad.

Mechling & Smith Tie, Wilkinsburg, Pa., Pennsylvania Railroad.

Carnegie Steel Tie, Port Perry, Pa., Union Railroad.

Carnegie Steel Tie, Homestead, Pa., Carnegie Steel Company.

Carnegie Steel Tie, North Bessemer to Exposition Park, Bessemer & Lake Erie Railroad.

And a meeting at Baltimore, Md., November 10, 1911.

In connection with the following report your Committee wishes to point out that it is of the opinion that no single design of substitute is going to meet all the conditions to be found on railway track and there should be at least two designs or types:

(1) A tie for heavy service, insulated or not insulated, as required.

(2) A tie for light service, insulated or not insulated, as required.

It is desirable that any type of non-insulated tie should be capable of being insulated without having to be removed from the track.

As far as we can see, very few designers have recognized this distinction and as a result attempt to meet all conditions with a single design. We believe this is neither desirable nor economical, and that much better results will be obtained if the tie be designed for special service.

Your Committee has been somewhat disappointed with the results obtained with the concrete tie, the concrete and metal tie, and the asphalt and metal tie, for reasons given in our conclusions.

In regard to steel ties, your Committee was impressed with the number of steel ties in use on the Union Railroad and the Bessemer & Lake Erie Railroad. The total number of steel ties on these two

roads is over one million, or enough to lay 312 miles of track, using 3,200 ties to the mile.

We desire to call attention to the widespread interest that is now being taken in finding a substitute for the wood tie. This is not confined to any particular section of the country, nor to the steam railroads. The portion of this report covering the Street and Interurban Electric Lines is evidence that these lines are seeking a substitute tie.

In addition to the personal inspection made by the Committee the following reports have been received from railroads using substitute ties:

Baltimore & Ohio Railroad Company:

(For previous reports see Vol. 10, Part 1, pp. 504-529; Vol. 12, Part 1, page 385.)

On October 28, 1911, Mr. Earl Stimson, Chief Engineer Maintenance of Way, states:

"In reply to your letter of August 26, I would advise that this company has made no additional installations of any metal or composite ties. I have nothing further to report thereon."

Bessemer & Lake Erie Railroad:

(For previous reports see Vol. 10, Part 1, page 496; Vol. 11, Part 2, page 876, and Vol. 12, Part 1, page 371.)

"Up to January 1, 1911, this company had purchased 563,555 Carnegie steel ties and during 1911 we will receive 138,000, making a total of 702,355 ties to be received by January 1, 1912. The ties if laid continuously 3,200 to the mile (our standard spacing on main line) would give 219.5 miles of steel tie track. During the year we also received 20 sets of steel switch ties.

"We have very little, if any, additional information to report this year. The ties put in at Claytonia in 1904 are still in and there has been no change in their condition since our last report. The 1,000 insulated ties installed in June, 1906, at Conneaut, Ohio, are still in and have given no trouble whatever.

"This road will continue to use this type of steel tie in maintenance and construction work.

"Accompanying this are two photographs, one showing scene of a derailment near Queen Junction, Pa., and one near Jamisonville, Pa. Both derailments were caused by a broken flange; in each case but one pair of trucks was derailed and the car derailed was a steel car loaded with 55 tons of ore, so that the gross weight of the car was about 73 tons. These derailments happened in August, 1910, and the ties are still in the track."

Buffalo, Rochester & Pittsburg Railway:

(See previous report, Vol. 12, Part 1, page 371.)

Mr. E. F. Robinson, Chief Engineer, says: "On account of the installation of automatic block signals, we are removing 1,500 Carnegie steel ties from the main track, near Ridgway, Pa. It is our intention to make no further increase in the use of this design of tie, at least for the present."

Chicago & Alton Railroad:

(See previous reports, Vol. 10, Part 1, page 515; Vol. 11, Part 2, page 893.)

Mr. E. L. Crugar, Assistant Chief Engineer, advised August 28,

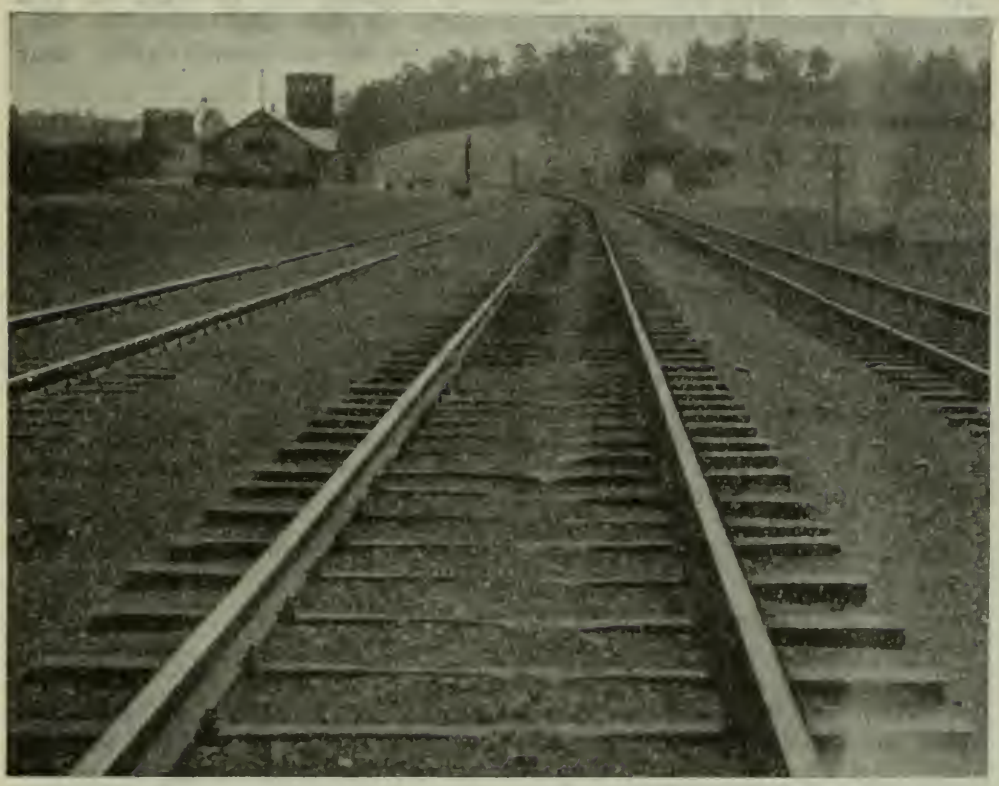


FIG. 1. BESSEMER & LAKE ERIE R. R., NEAR QUEEN JUNCTION, PA.

FIG. 2. BESSEMER & LAKE ERIE R. R., NEAR JAMISONVILLE, PA.

1911: "There have been no changes as regards ties in track on this company's lines. We have put in no metal or composite ties."

(This line placed 63 "Kimball" ties in its southward track, near Lockport, Illinois, October, 1905.)

Cleveland, Cincinnati, Chicago & St. Louis Railway:

(See Vol. 11, Part 2, page 887; Vol. 12, Part 1, page 383.)

On August 28, 1911, Mr. C. A. Paquette, Assistant Chief Engineer, advised: "Answering your letter of the 26th instant, we have no additional information to give you as to steel ties which are in service in our main track.

"In November, 1909, there were 20 concrete ties made under the Israel patent and put in the main track east of Paris, Ill., on our St. Louis Division. On February 12, 1911, we found it necessary to remove three of these ties from the track, the ties having failed completely. The concrete was crushed and the top plate, which reaches half way across the tie and serves as a support for the rail fastenings, was broken in several places. As to the balance of the ties 85 per cent. of them have the top plate either cracked or broken.

"This experience seems to indicate that these ties are not suitable. Their life may be considered to be about two or three years, and the cost is considerably greater than that of wooden ties."

Cornwall & Lebanon Railroad:

On October 16 Mr. A. D. Smith, President and General Superintendent, advised as follows (for design see P. R. R. report):

"With reference to our experience with the 200 Snyder steel ties which were installed in our road about five years ago, these ties are located on the southbound track of our double track, lying about one mile west or south of Mount Gretna in a 2-degree curve and on a 1.5 per cent. descending grade. One coat of tar paint was applied when the ties were put in and another coat during the past year. This is about the only expense we have been put to in the matter of maintenance.

"A few months ago in passing over this part of the road it was noticed that the asphalt concrete filling showed signs of disintegration at the open ends of the ties and upon investigating we found as far back as the hand could be placed that the filling was loose and in particles. In order to ascertain how far in this extended the tie was taken out of the track and in pulling the tie out the filling was left on the ground under the rails, simply a mass of particles. We imagine that as a result of this condition whenever the ties are tamped some material will be dropped from the bottom through the slight raising due to the tamping. The track foreman reported that he had noticed the material loosened in this manner several months ago. The track at this point is laid with 80-lb. rail and on stone ballast.

"Approximately half a million tons of freight per year pass over this track in the southward direction, our heaviest locomotives being 75 tons in weight, not including the weight of the tender. During the summer season eight or ten passenger trains pass over this track daily and four passenger trains the remaining portion of the year, probably at a speed of 40 or 50 miles per hour.

"There has been no trouble at all in connection with these ties as stated, except the recent crumbling of the asphalt filling. Just what the effect of this would be eventually we are not prepared to say:

Duluth & Iron Range Railroad:

(See previous reports, Vol. 11, Part 2, page 890; Vol. 12, Part 1, page 384.)

Mr. W. A. Clark, Chief Engineer, advised August 28, 1911, that he has nothing additional to offer. "The ties covered by our last report are still in the track and giving satisfactory service."

Duluth, Missabe & Northern Railway:

Mr. H. L. Dresser, Chief Engineer, under date of September 11, 1911, writes as follows:

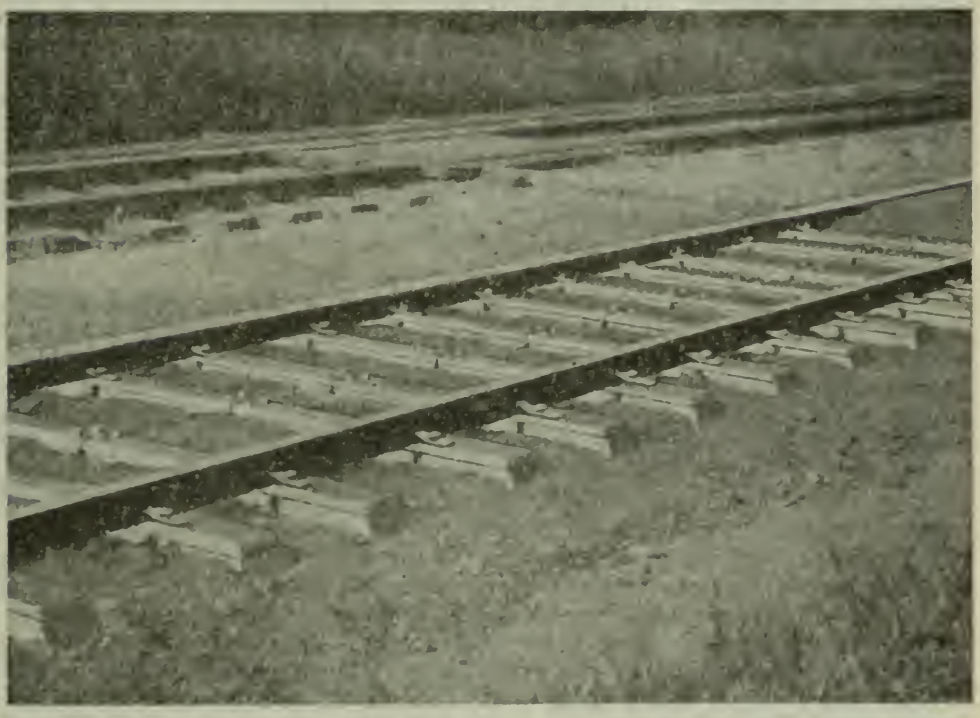


FIG. 3. ISRAEL SECTIONAL TIE.

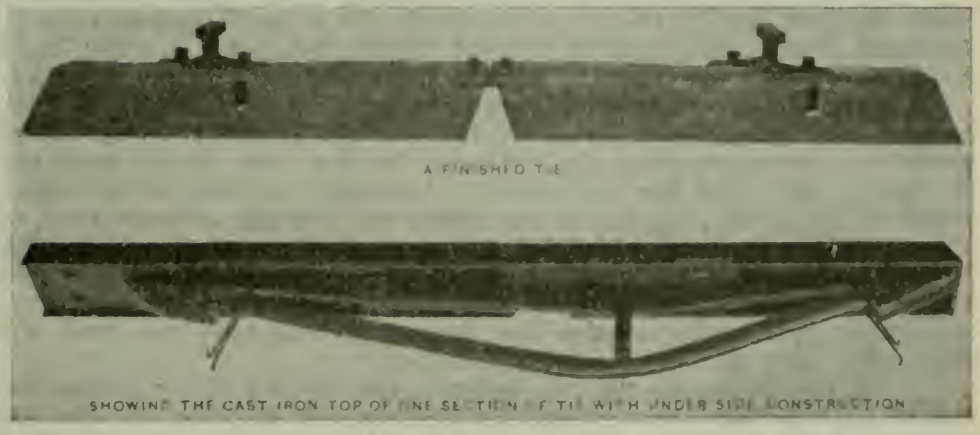


FIG. 4. ISRAEL SECTIONAL TIE.

"Your letter of September 8, in regard to a report as to the steel ties which we have in use on our line; we have about 22,400 ties of the Carnegie Steel Company's Section M-21. They were purchased in the summer of 1908 and we started to put them in the track in the fall after

the ore business closed, but the work was not completed until the spring of 1909. Two miles of these were placed on the hill between Duluth and the yards at Proctor, being placed in the double track, one mile in each track. This portion of the road had been previously ballasted with crushed granite and consequently required less work to place them than it did the others, which were placed where the track crosses the big muskeg swamp about fifty miles north of Duluth. This is also double track and we have two and one-half miles of these ties in each track. This portion of the road had been ballasted with gravel and had always cost us a great deal to maintain during the summer season on account of the nature of the soil underneath the roadbed. It was necessary to keep the track lined with men during the ore season to keep the track in shape and to keep the rails spiked to line, although we were using tie-plates, but owing to the shaking and trembling of the ground underneath which set up a vibration in the train the rails were continually spreading and it was necessary to line spike this track every season, and more or less would have to be lined up two or three times during the summer.

"We removed the old ballast and replaced it with crushed granite, leaving the original roadbed underneath the granite sloping from the center between the two tracks, as shown in the accompanying blueprint. Owing to this work having been done in the winter when there was a great deal of snow on the ground and more or less ice, these tracks required considerable attention during the summer of 1909, but by the time winter set in we had these tracks in elegant shape and during the summer of 1910 we did no more work on them whatever. Of course, the section men passed over them going to and from their work, but no work was done in either surfacing or lining during the entire summer, which was something very unusual for that track. It kept in very good shape until late in the fall, at which time by careful inspection you could see that some places were slightly depressed, but it was scarcely noticeable in the running of trains. Early in the season of 1911 we sent an extra gang over this track and brought it to surface again. Since that time no work has been required on it, although we have had a large amount of rain in that district this summer.

"We would say that with these ties, placed 18-in. centers as we have them, carrying 100-lb. rail, it is impossible for a small section crew to line and surface the track to a great extent, but needs a small extra gang to handle it, as it is exceedingly heavy and hard to move. However, it requires so much less attention than our old track with the wooden ties and 80-lb. rail that we feel there is economy in the use of these ties, notwithstanding the difference in first cost of the steel and the wood, and would like very much to have them to place on the entire length of the main line, but as our tracks run through a forest most of the way where the settlers are getting out track ties more than any other material and ship them over our road, our people feel that we ought to use their product while it lasts, as it will be but a very few years before all timber suitable for wooden ties lying anywhere near our road will have been used up.

"The two miles on the hill between Duluth and Proctor have required scarcely any attention since they were put in place, but the soil underneath the roadbed at this point is solid clay and has never caused the trouble the tracks across the big swamp have. There are two light curves on the latter two miles and we have worn out the new rail which was placed with the ties in some instances on these curves, but the cost of surfacing and relining the track has been very light as compared with the tracks on the wooden ties.

"Accompanying this is a sketch showing our standard section of road-

bed where steel ties were used, and also a blueprint showing the tie and fastenings. This print shows a clip and stop on each side of the rail on each tie, which was the plan suggested by the Carnegie Steel Company, and when the time arrived they were drilled in this manner, but we never used the stop on the gage side of the rail, as we looked upon it as useless. We have, however, used the clip and the stop both on the outer side of the rail and they have had no trouble with broken clips, loose bolts, or anything of that nature, and are very much pleased with the service they have given up to this date."

Elgin, Joliet & Eastern Railway:

Mr. A. Montzheimer, Chief Engineer, advises as follows: "We have put in this year 500 Carnegie Steel Company ties. These are located on the main line, between Gary and South Chicago. We are now making up list of switch ties for next year and expect to be able to make our next year's renewals of switch ties, consisting of about 350 sets, with Carnegie steel ties. In addition to above we are planning to use Carnegie steel ties on all renewals on main line on curves."

Erie Railroad:

(See previous reports, Vol. 12, Part 1, p. 386.)

On October 7, 1911, Mr. W. J. Harahan, Vice-President, advised as follows: "No further installation of metal ties has been made since the report of November 30, 1910, was made, and therefore the Carnegie steel switch ties at Bergen are the only ties of this character in use. In regard to these ties, would advise as follows: The original 57 ties are still in service. One of these ties was broken off outside the rail and fastenings by derailment of a car August 30, 1911. The derailment was caused by yardmaster not getting the switch over in time. Otherwise, these ties are practically as good as new.

"In regard to the fastenings supplied with these ties, they are too small for the service required of them, and as the effect of rust on them is very great, they soon fail and have to be renewed. The fastenings on these ties have all been renewed once, and some of them twice since the original installation was made, which was in April, 1909.

"As regards the desirability of these steel switch ties compared with ordinary yellow pine switch ties, would state they compare favorably, except in the matter of fastenings, which feature could be improved very much by the use of heavier bolts and clips, and lohmanized material."

Galveston, Harrisburg & San Antonio Railway:

(For previous reports see Vol. 11, Part 2, page 894.)

Mr. D. K. Colburn, Engineer Maintenance of Way, advises that they have installed 200 Percival Reinforced Concrete Ties, 100 at Bayou Sale, La., January 20, 1910, and 100 at Edgewater, Texas, October 22, 1906.

At Bayou Sale the ties were installed under 76-lb. rail, gravel ballast. Traffic at this point low speed and rather heavy. The ties are located at end of double track where fires are cleaned and the concrete ties are thus far satisfactory in all respects, except that the wood cushions under the rail have been somewhat damaged by fire, but their renewal is an easy matter.

At Edgewater the ties are under 80-lb. A.S.C.E. rail gravel ballast. Fifty ties at this point were installed consecutively, 18 ties to a 33-ft. rail, and 50 were placed alternately with cypress ties. Traffic over these ties is high speed and rather heavy, and at the time of making this report (September 7, 1911), they were in good condition, except for a few minor cracks.

(For design of this tie see Figs. 5, 6 and 7.)

In regard to shape of this tie the patentee, Mr. Percival, advises that the tie is made wider at the top than elsewhere and of somewhat rounded bottom for the following reasons:

1. For easy tamping.
2. Economy and better utilization of reinforcement.
3. For reduction of section and consequent weight.

Mr. Colburn further advises that these ties are made up as follows:

Composition: Six parts clear granite crushed very fine. Two and one-half parts crushed sandstone (largest piece passes through a one-inch ring). Two parts Whitehall cement.

Reinforcement: Three ½-in. corrugated bars in face. One ¾-in. corrugated bar in base.

The bars are bound together with strong wire, making a truss; total weight of reinforcement 25 lbs., total weight of tie 445 lbs., cubical contents of tie 3.385 cu. ft.

Lake Shore & Michigan Southern Railway:

(See previous reports, Vol. 10, Part 1, page 511; Vol. 12, Part 1, page 384.)

On September 20, 1911, Mr. Samuel Rockwell, Chief Engineer, advised: "At one time we had steel ties on several divisions of the road in experimental stretches, but a few years ago they were all taken out. One of the chief troubles we had with them was the insulation. A number of them have now been put in on our Sandusky pier branch where the speed is limited, and we have no need of insulation, and where we run in streets part of the way and good permanent construction is needed. They are well adapted for this service.

"These ties are mostly of the Buhrer pattern, made by the Carnegie Steel Company, with four clip fastenings for each tie. They have been in track for about six years and are in first-class condition at this time. The Roadmaster is of the opinion that they will last from ten to fifteen years longer. They hold the track in line, surface and gage very well, but our people are not yet convinced that they are the tie for our main line with its heavy high speed traffic."

Lake Terminal Railway (National Tube Company):

(See previous report, Vol. 11, Part 2, p. 890; Vol. 12, Part 1, p. 384.)

Mr. F. W. Waterman, Engineer, advises, Sept. 5, 1911: "We placed 18,645 Carnegie Section M-21 steel ties since January 1, 1911, and expect to replace all our wooden ties as fast as they are worn out, with steel ties."

Long Island Railroad:

(See previous reports, Vol. 12, Part 1, page 386.)

Mr. E. M. Weaver, Engineer Maintenance of Way, says, September 6 1911: "I have nothing whatever to offer in the way of a report."

Michigan Central Railroad:

(See previous reports, Vol. 12, Part 1, page 386.)

Mr. G. H. Webb, Chief Engineer, on August 29, 1911, says: "There is very little to add to my report of November 19, 1910, with the exception that the few concrete ties which we have in our track at Jackson, Mich., are still in service, though they are somewhat cracked, but not enough so as to necessitate their being taken up. We are not contemplating any further installations of metal or composite ties at this time."

Northern Pacific Railway:

(See previous report, Vol. 12, Part 1, page 384.)

On August 30, 1911, Mr. W. C. Smith, Chief Engineer, Maintenance

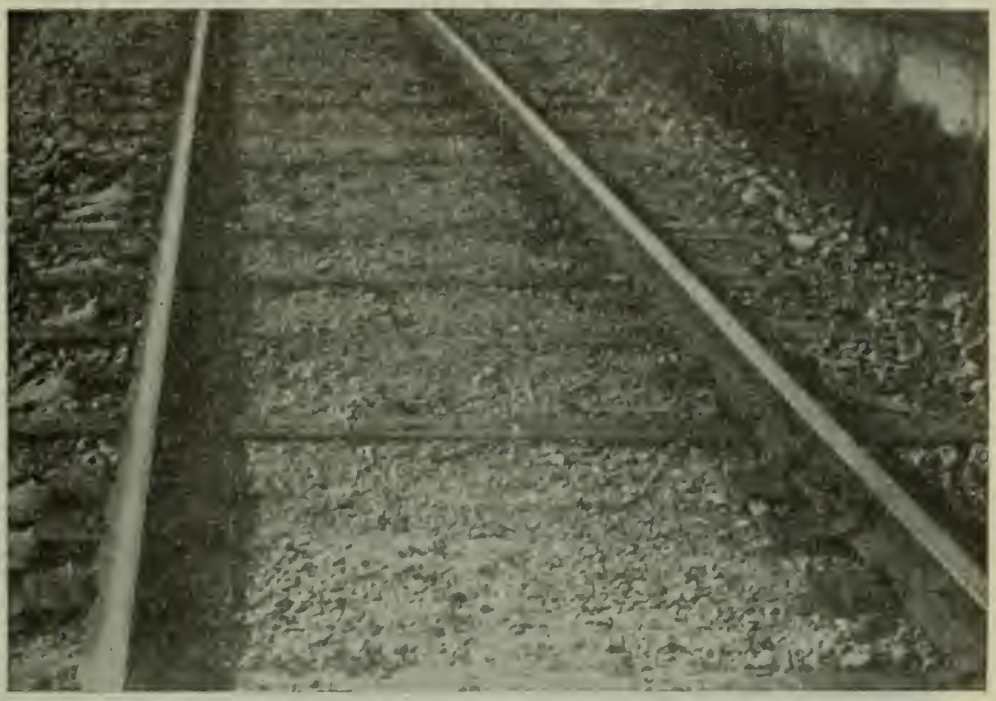


FIG. 5. PERCIVAL CONCRETE STEEL TIES.

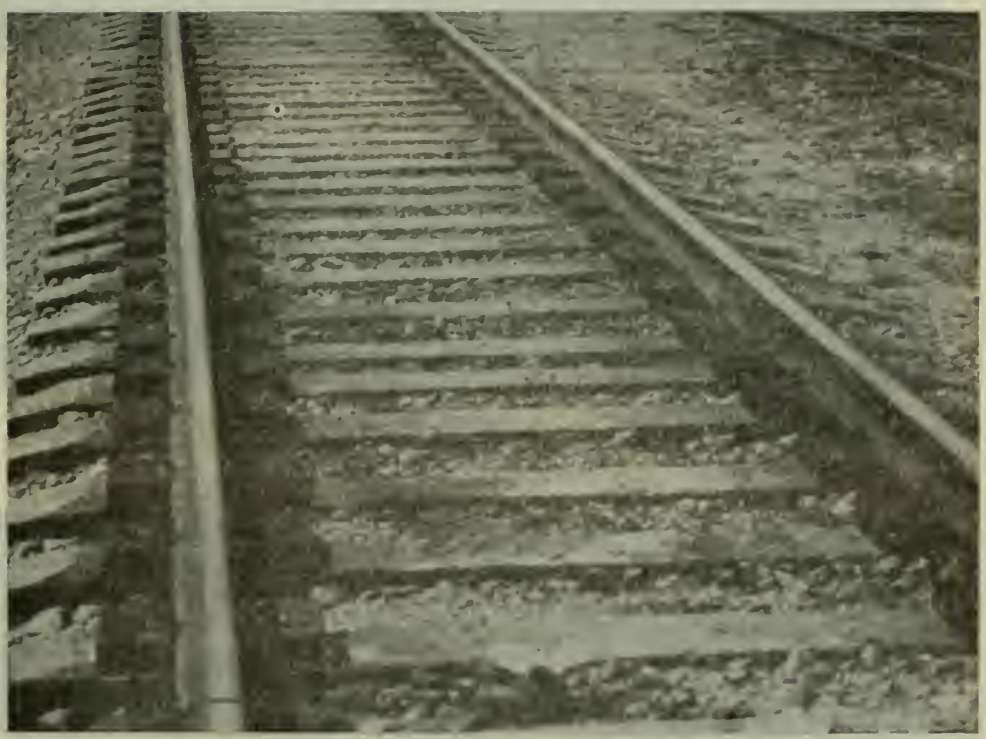


FIG. 6. PERCIVAL CONCRETE STEEL TIES.

of Way, advised: "We have made no additional installation during the past year. In fact, we have removed a few of the metal ties and transferred some to other points so as not to conflict with automatic block signals which we have been placing. We are finding it very difficult to properly insulate them. The few ties which we have in place have given excellent satisfaction. We are simply using them at a number of points where engines take coal and water, and where cinders are likely to be dropped."

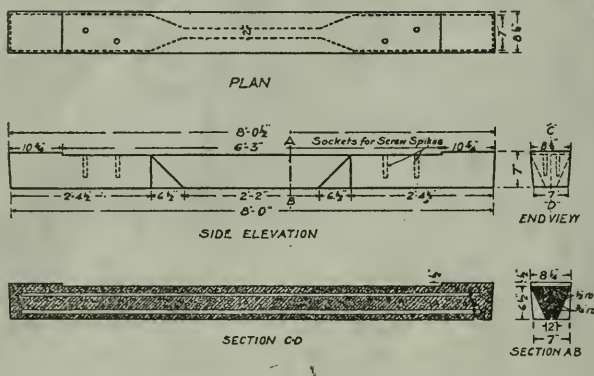


FIG. 7. PERCIVAL REINFORCED CONCRETE TIE.

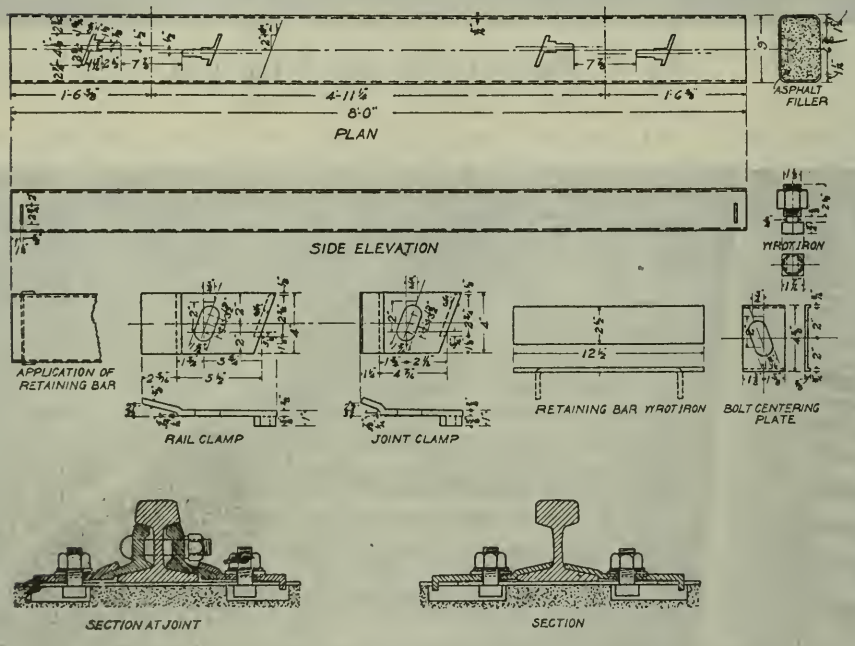


FIG. 8. SNYDER STEEL TIE FOR 100-LB. RAIL.

Pennsylvania Railroad:

(See previous reports, Vol. 10, Part 1, page 509; Vol. 11, Part 2, page 891; Vol. 12, Part 1, page 378.)

Your Committee inspected the "Snyder" ties installed at Derry on September 6, 1911. As will be seen from previous reports, 1,600 of these ties were put in during the summer of 1907 in Conemaugh yard and 966 in Derry yard, both on the Pittsburg Division. In these locations they are used for heavy but slow traffic. This tie consists of a steel shell

3/16-in. thick, the ties are 8 ft. long, 7 ins. wide, 7 ins. deep, and open on the bottom. The interior of the shell is filled with a mixture of asphalt and crushed stone, the rails are fastened to the tie by bolts and clips, and these ties weigh 700 lbs. per tie. (See Fig. 8 for details of tie and fastenings.) Our inspection developed that the metal of the

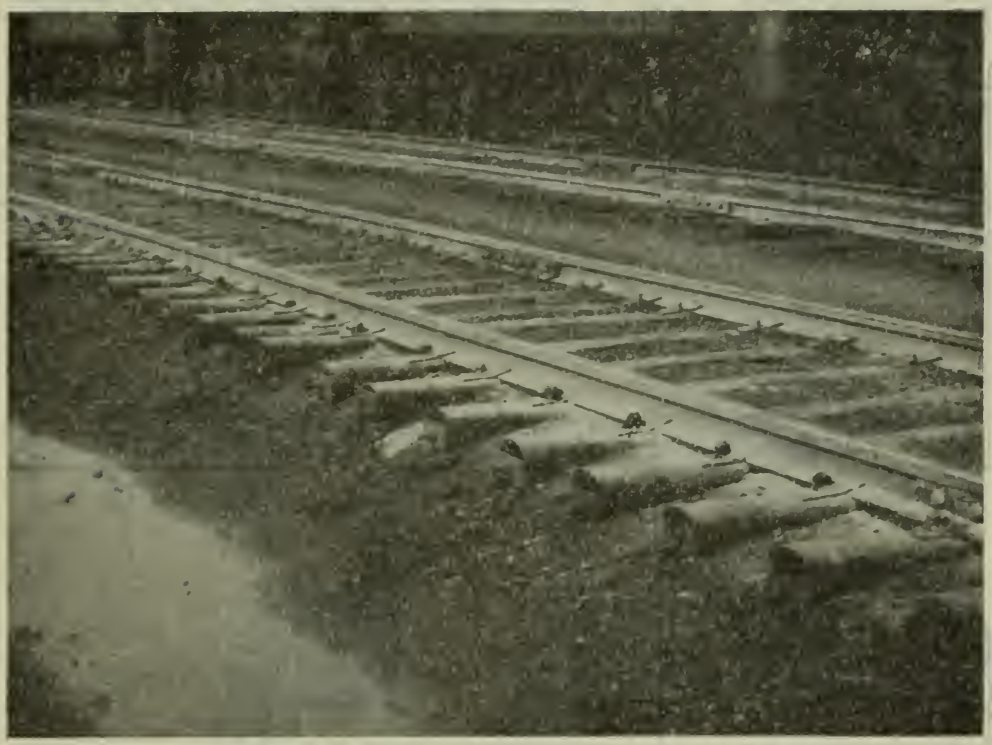


FIG. 9. SNYDER TIE, PENNSYLVANIA RAILROAD, DERRY, PA.

FIG. 10. SNYDER TIE, PENNSYLVANIA R. R., SHOWING ASPHALT FILLING HAVING DETERIORATED.

FIG. 11. SNYDER STEEL TIE, PENNSYLVANIA RAILROAD, DERRY, PA.

tie is in good condition, showing very little if any loss from corrosion, that the fastenings were holding well, but that on about 20 ties the mastic was disintegrating so that it was falling out of the ends of the ties. (See photographs Figs. 9, 10 and 11.)

Your Committee also examined an experimental tie owned by Mechling and Tiechart, Munhall, Pa., of which the Pennsylvania Railroad has installed 100 near Wilkinsburg, Pa., on the Pittsburg Division. (See Fig. 12 for the design of this tie.)

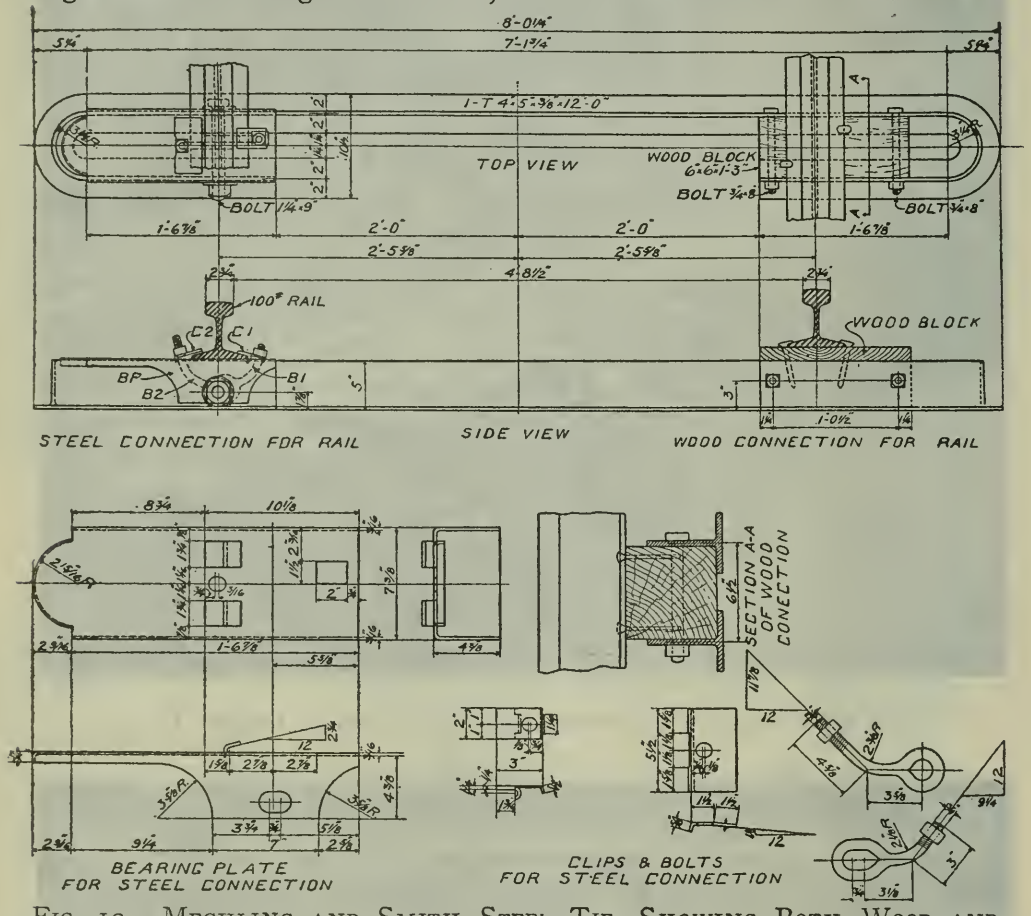


FIG. 12. MECHLING AND SMITH STEEL TIE, SHOWING BOTH WOOD AND STEEL RAIL CONNECTIONS.

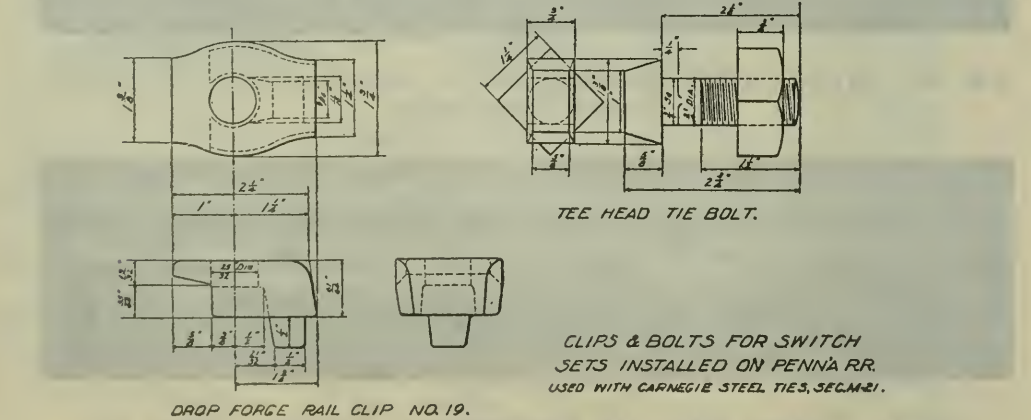
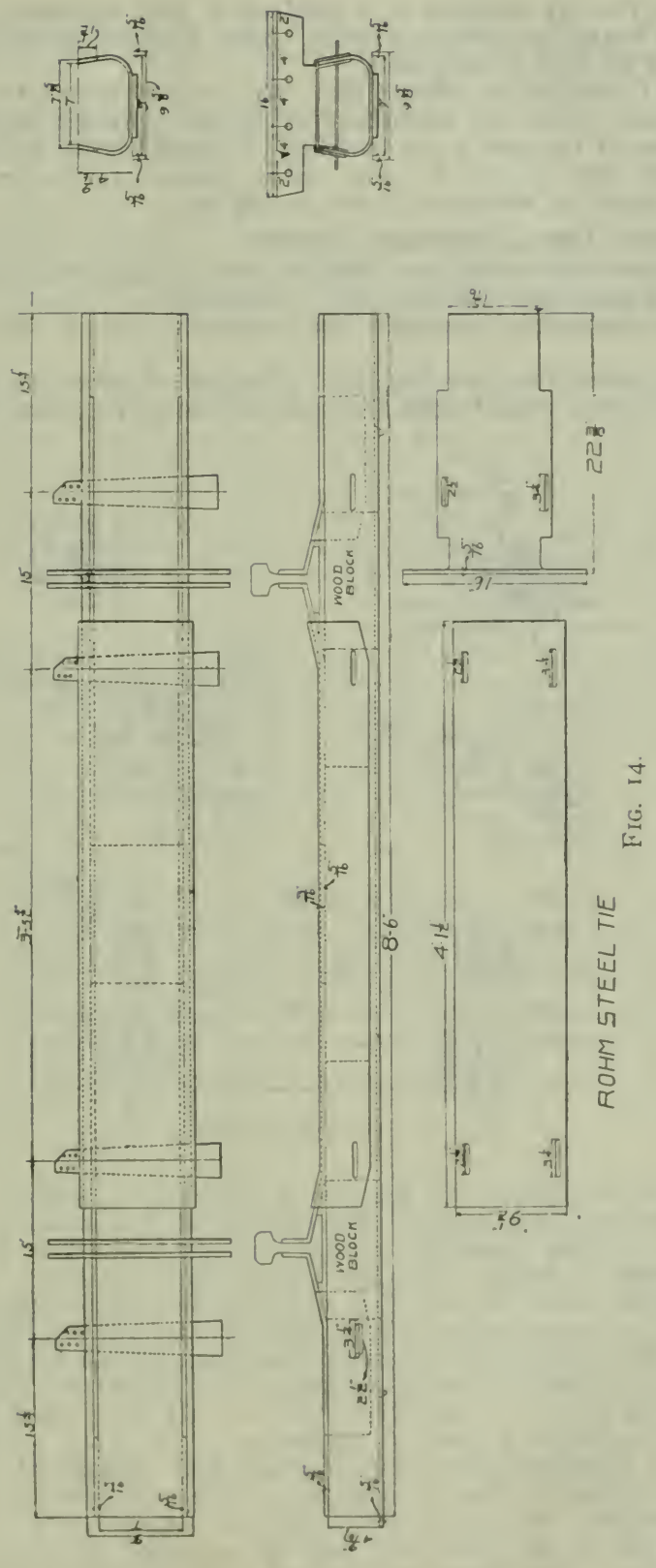

TEE HEAD TIE BOLT.
CLIPS & BOLTS FOR SWITCH SETS INSTALLED ON PENNA R.R. USED WITH CARNEGIE STEEL TIES, SEC. M-21.
DROP FORGE RAIL CLIP NO. 19.

FIG. 13.



ROHM STEEL TIE

FIG. 14.

These ties are installed in a yard track (not insulated) over which there is a heavy but slow movement. Your Committee thinks this tie is capable of further development.

Your Committee is advised that this company is about to install six sets of steel switch ties manufactured by the Carnegie Steel Company. The section of tie used is the modified "I" beam known as Section M-21 and weighs 19.7 lbs. per ft. The rail is fastened to the tie with a bolt and clip, details of which are shown in Fig. 13.

Pennsylvania Lines, Northwest System:

(For previous reports see Vol. 10, Part 1, page 505, page 513; Vol. 11, Part 2, page 892; Vol. 12, Part 1, page 383.)

Your Committee examined the following ties in this company's tracks:

Rohm Steel Tie (see Fig. 14): Twelve of these ties were placed in the eastbound main freight track at Sewickley, Pa., June, 1910. They

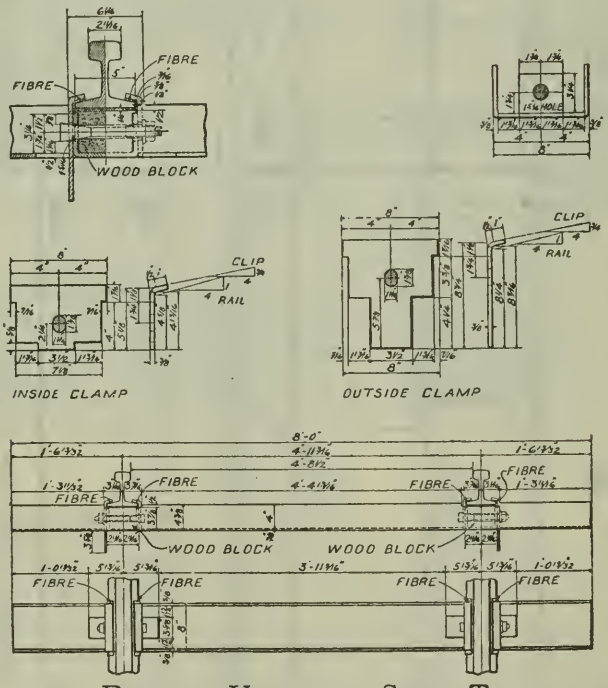


FIG. 15. UNIVERSAL STEEL TIE.

are still in the track and are giving satisfactory service. The only trouble these ties have caused has been with the insulation, which Mr. A. A. Wirth, Division Engineer, pointed out could be taken care of by a slight change in design. This tie weighs about 260 lbs.

Universal Steel Tie (see Fig. 15): Ninety-eight of these ties were installed in eastbound main freight track near Emsworth, Pa., in December, 1910. The Supervisor in charge of this track pointed out that these ties would be very hard to line on account of the projection of a portion of the fastening below the bottom of the tie. He also stated that it was very hard to hold this track in surface.

Reigler Combined Steel and Concrete Tie: Details of this tie will be found in Vol. 11, Part 2, page 893. Fifteen of these ties were put in the westbound main passenger track near Emsworth, Pa., May, 1908. They are still in the track and with the exception of three ties are in good condition. The three ties referred to show signs of failure under

the rail, but the inventor thinks that repairs can be readily made so that the ties will be restored to their original condition. One other feature noticed by the Committee was that several of the nuts were loose and that same could not be tightened unless ties are taken out of the track. This could be taken care of if the shape of bolt were such that it would not turn in the hole through the concrete.

Pittsburg & Lake Erie Railroad:

(For previous reports see Vol. 10, Part 1, page 503; Vol. 11, Part 2, page 883; Vol. 12, Part 1, page 375.)

Your Committee inspected the experimental ties on this road in September, 1911, and as a result of this inspection would advise as follows:

Carnegie Steel Ties with Wedge Fastening: The six ties placed in the northbound main track at Pittsburg Terminal Station, May, 1908, are still in the track. The fastenings on these ties were for 90-lb. A.S.C.E. rail and during the past year 100-lb. A.R.A. section B rail has been laid at this point, without any change in fastening. The Supervisor informed the Committee that they have trouble in keeping the wedges tight with the new section of rail, and previous report (Vol. 12, Part 1, page 375) states that this same trouble was experienced with the 90-lb. rail.

With Bolt and Clip Fastening: As previously reported, 3,000 ties of this design were laid in August, 1907, at McKees Rocks. Last year's report indicated that the fiber installation on these ties was approaching the end of its life, yet the Supervisor in charge of this section informed your Committee that they had experienced no trouble from this cause as yet. Your Committee could see, of course, that the fiber is deteriorating, but they think that in view of the fact that the fiber is placed directly under the rail and not protected as the later design of this tie is now furnished (Vol. 12, Part 1, page 734) excellent results have been obtained from this fiber.

Universal Metal Tie: One hundred of these ties (see Fig. 11 for plan of this tie*) were installed in northbound main track Pittsburg Terminal, February, 1911. No joint ties were placed, as can be seen in photograph of these ties (see Fig. 16). The ties have not been in long enough for your Committee to draw any conclusions therefrom.

Atwood Concrete Steel Tie: Five ties of this design were placed in No. 4 main track, McKees Rocks, Pa., in October, 1908. Your Committee found these ties in good condition; track was in good line and surface and the Supervisor advised that they had had no trouble with the insulation. (See Vol. 12, Part 1, page 379, for design of this tie.)

Bruckner Reinforced Concrete Tie: Your Committee were shown 20 of these ties which had not been installed at the time of our inspection. Photographs of these ties were furnished, however, by Mr. Edwin F. Wendt, Assistant Engineer, and they are shown in Figs. 17, 18 and 19.

One tie weighed showed a total weight of 345 lbs., while the steel plates, fastenings, etc., weighed 25 lbs.

International Steel Tie: The International Steel Tie Company, Cleveland, Ohio, advise that they have installed 24 of these ties on this road near Glassport, Pa. Design and photographs of these ties are shown in Figs. 20-23.

In addition to the above, Mr. Edwin F. Wendt, Assistant Engineer, has kindly furnished the Committee with the following information in regard to cost of maintaining Carnegie steel ties mentioned above and

*See Pennsylvania Lines, N. W., for plan.

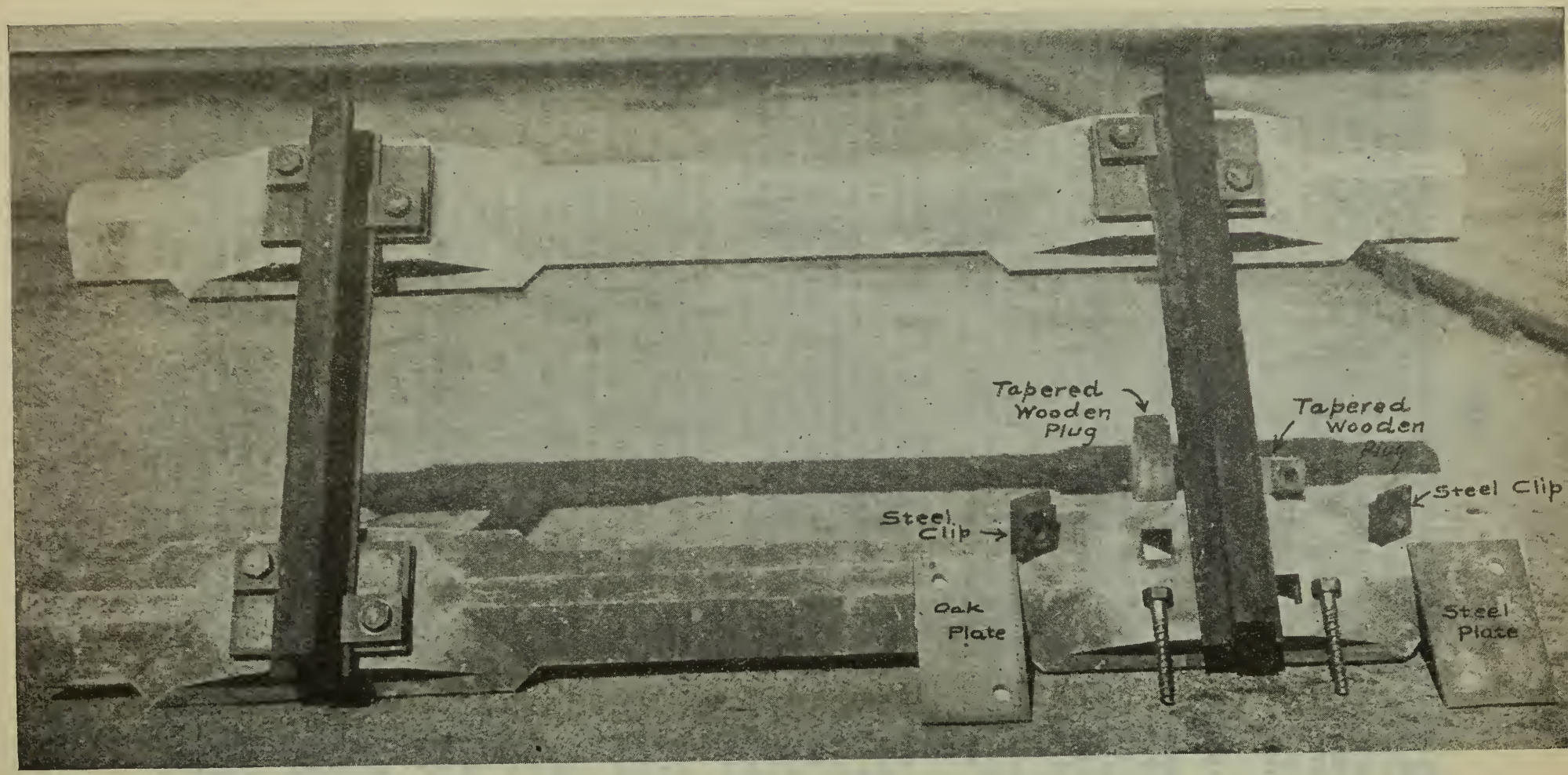


FIG. 17. BRUCKNER REINFORCED CONCRETE CROSS-TIE, PITTSBURG & LAKE ERIE RAILROAD.

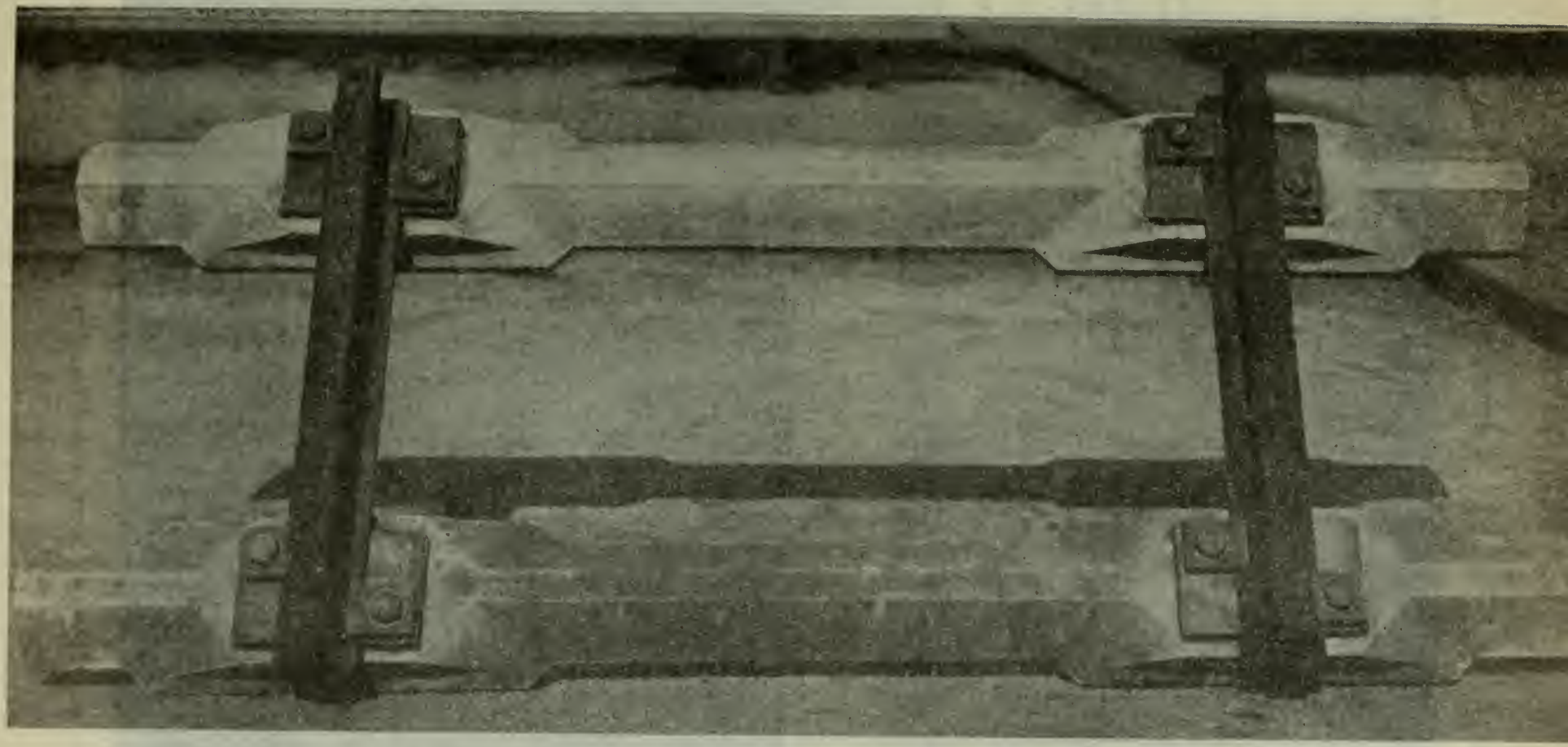


FIG. 18. BRUCKNER REINFORCED CONCRETE CROSS-TIE, PITTSBURG & LAKE ERIE RAILROAD.

which were installed August, 1907 (bolt and clip fastenings), as compared with a like stretch of wood ties:

Calendar Year.	Length of Experimental Track Section	Carnegie Steel Ties, Cost of Labor.	White Oak Ties, Cost of Labor.
1908.....	4,400 ft.	$280.00	$417.00
1909.....	" "	153.00	95.00
1910.....	" "	428.00	128.00
1911.....	" "	184.00	116.00

These experimental sections of track were built with new material and new limestone ballast in 1907. The maintenance record begins with the calendar year 1908.

These ties were laid in the main line freight tracks, equipped with electric circuits in connection with automatic semaphore signals. Tracks are used by freight trains only, which run at a speed of about thirty (30) miles per hour.

During 1911 it was necessary to resurface the steel tie track three times and the white oak track once.

During the year 1911, fiber plates were removed from track on account

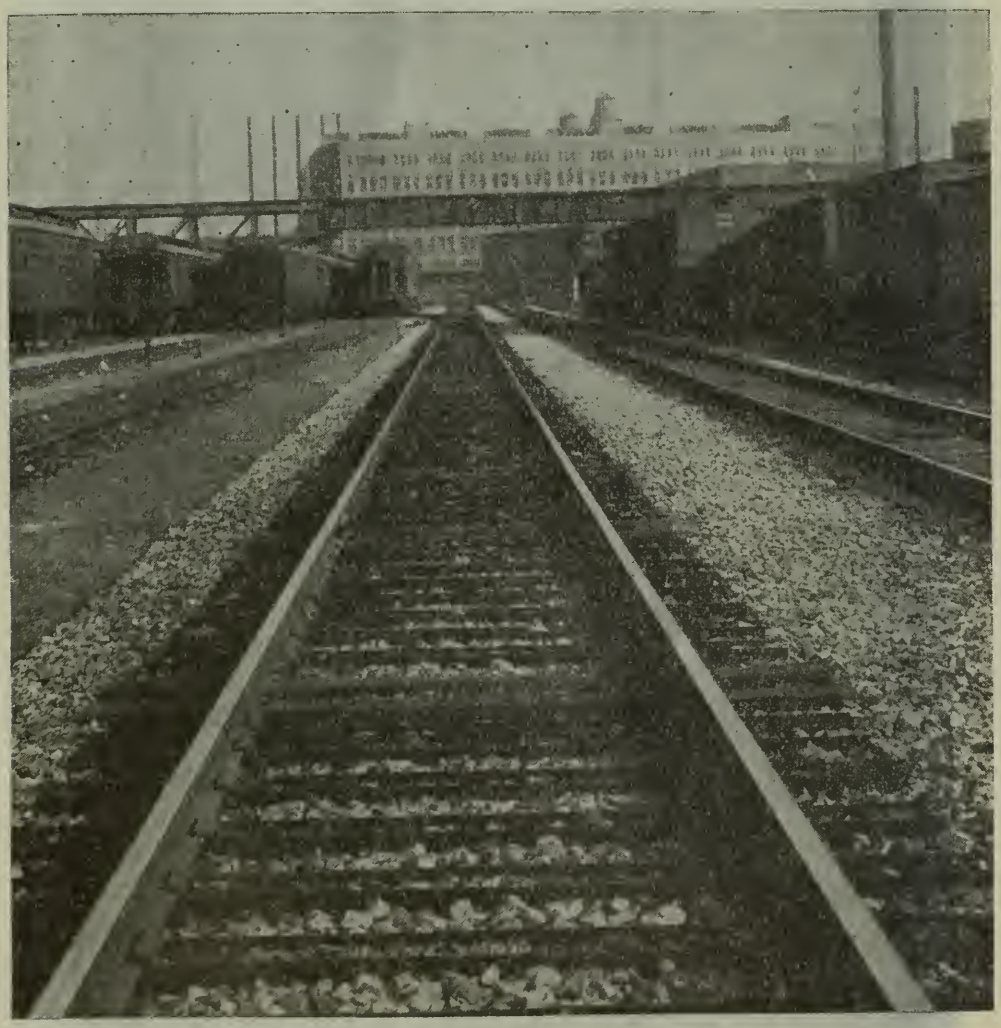


FIG. 16. UNIVERSAL METAL CROSS-TIE, PITTSBURG & LAKE ERIE RAILROAD.

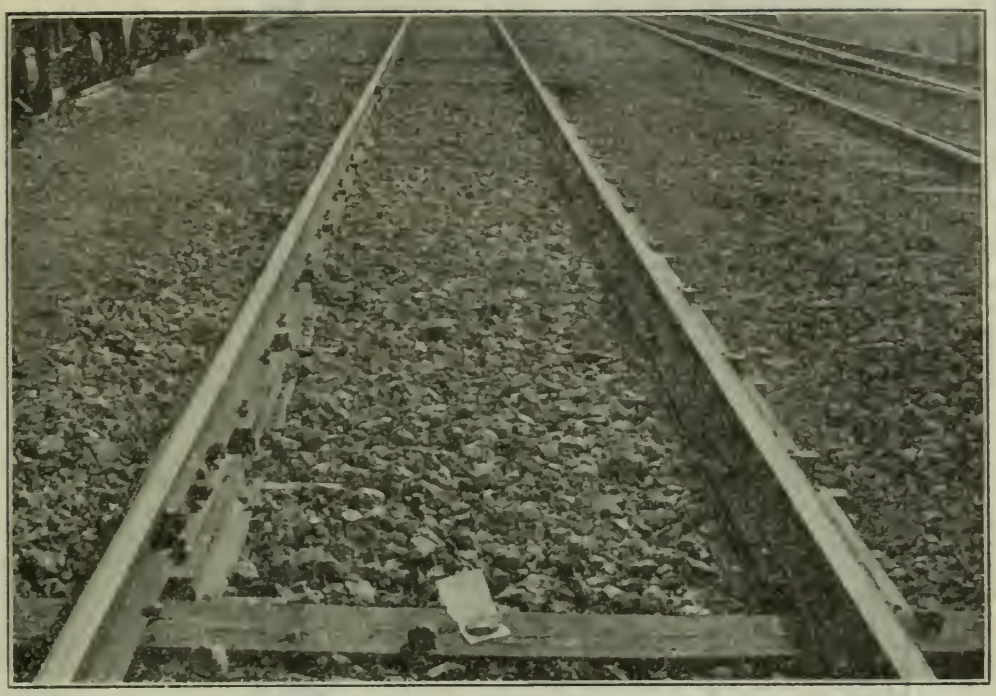
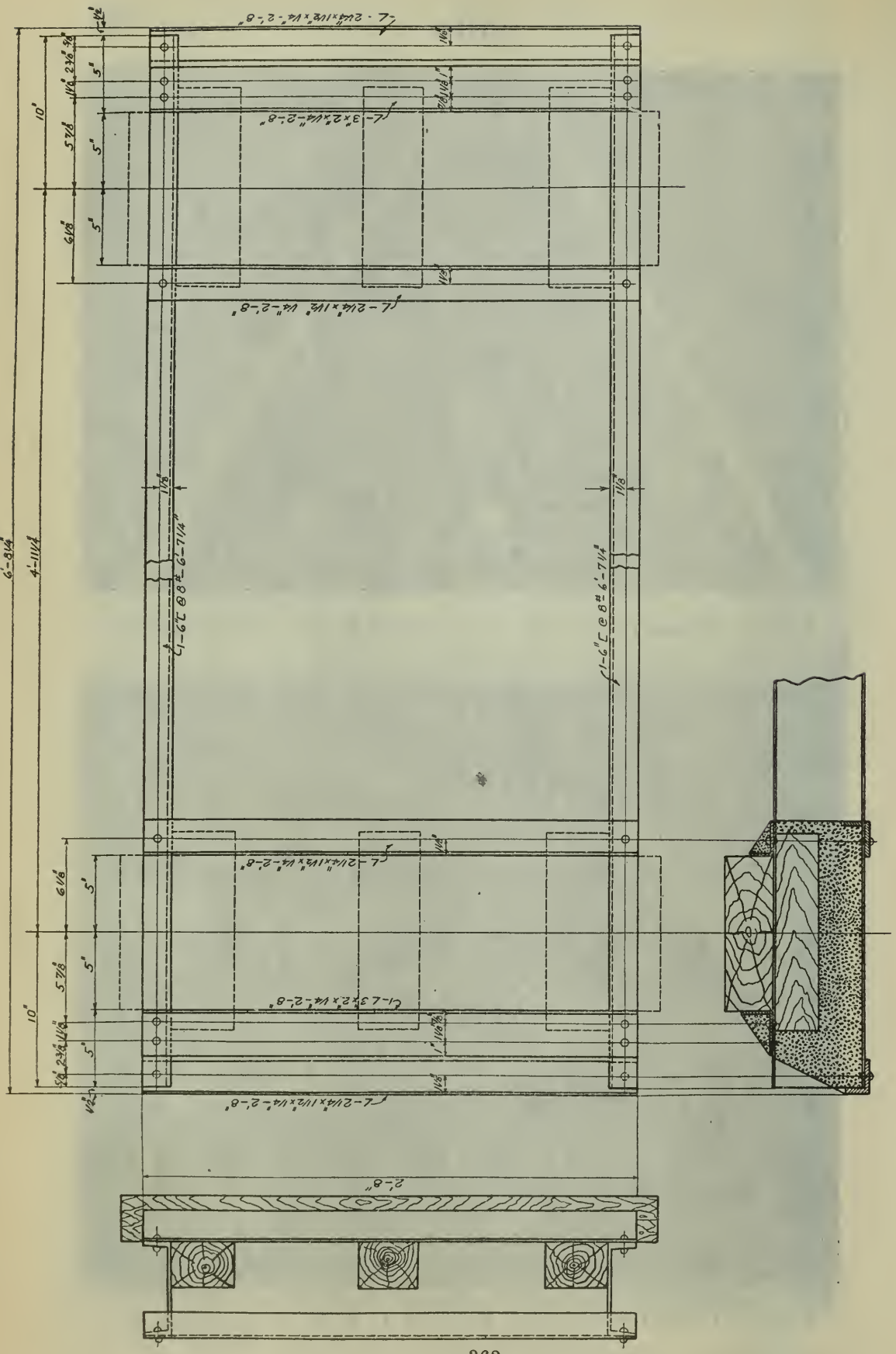


FIG. 22. INTERNATIONAL STEEL TIE, P. & L. E. R. R, GLASSPORT, PA.

FIG. 25. INTERNATIONAL STEEL TIE, P. & L. E. R. R., GLASSPORT, PA.


6'-9¼"
4'-11¼"
10'
5'-2¾"
5'-7⅛"
6'-1⅛"
5'
5'
5'
5'
5'
5'
2'-8"
L-2½"x1½"x¼"-2'-8"
L-3"x2"x¼"-2'-8"
L-2½"x1½"x¼"-2'-8"
L-3"x2"x¼"-2'-8"
L-2½"x1½"x¼"-2'-8"
L-2½"x1½"x¼"-2'-8"
1½"
1½"
1½

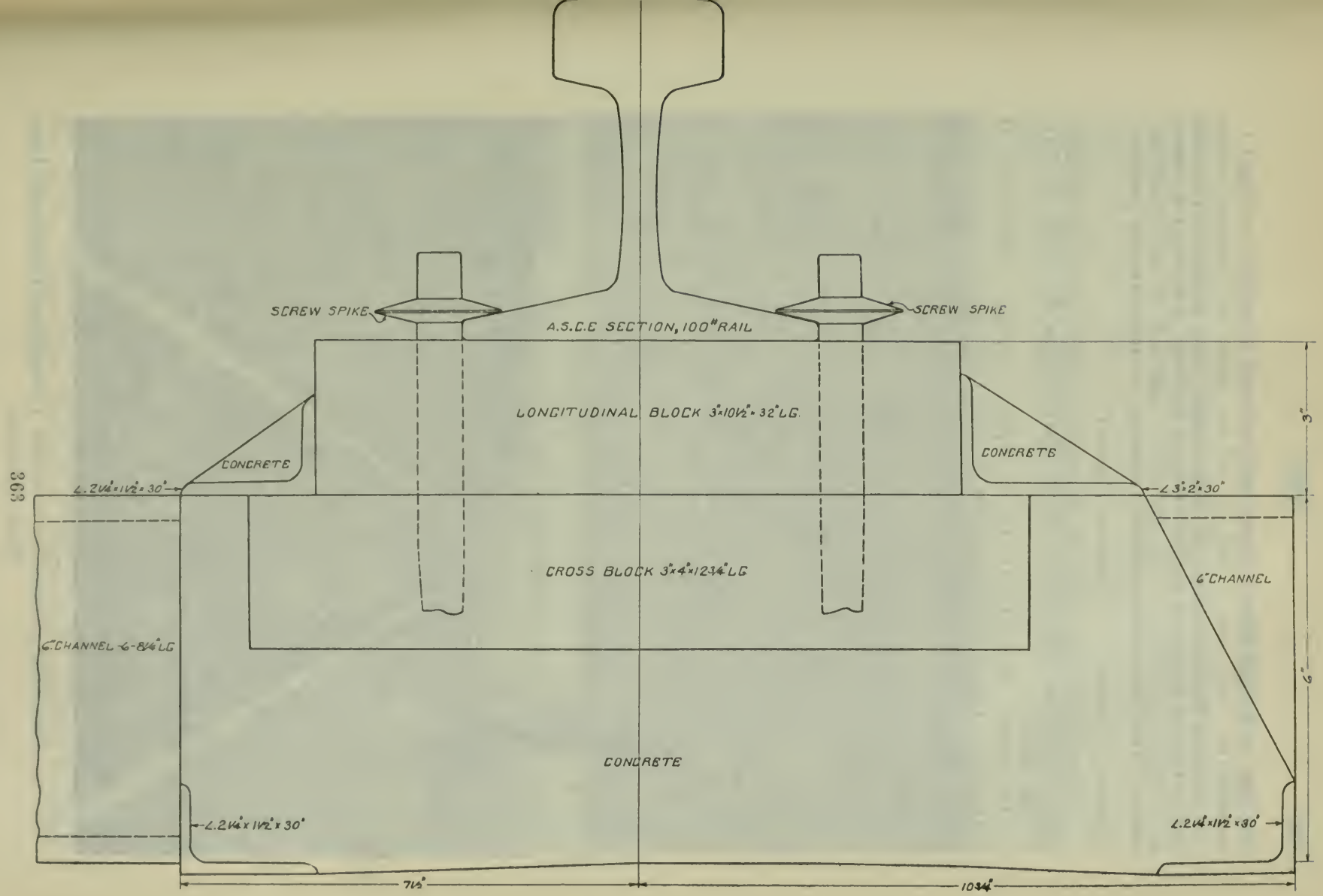


FIG. 21. THE INTERNATIONAL STEEL TIE. SECTION OF STEEL FOR INSULATION BLOCKS.

of being cut by rail base. Twenty bolts in steel tie clips were found to be loose.

It is now January 1, 1912, 52 months since these steel cross-ties were laid in the track and the record of the insulations shows that no fibers were renewed previous to 1911, and in that year only 17 were found defective. There has been, practically speaking, no signal trouble whatever.

Pittsburg Shawmut & Northern Railroad:

(Previous advices state this company installed about 795 of Carnegie ties during 1907. See Vol. 10, Part 2, page 885; Vol. 12, Part 1, page 383.)

On August 28, 1911, Mr. H. S. Wilgus, Engineer Maintenance of Way, says: "I have nothing further to report except that the ties contine to give full satisfaction. No new ties have been installed and further installation of the metal tie is not contemplated at this time."

Union Railroad:

(For previous reports see Vol. 10, Part 1, page 504; Vol. 11, Part 2, page 378, and Vol. 12, Part 1, page 378.)

Mr. W. S. Gibson, Engineer Maintenance of Way, advises that they have purchased up to September 1, 1911, 310,116 Carnegie steel cross-ties and 392 sets of Carnegie steel switch ties, and that during the remainder of the year 1911 they will purchase 30,000 additional steel cross-ties and 50 sets of steel switch ties.

Your Committee made a careful inspection over a large part of the main line of this road and they were very favorably impressed with the service these ties are giving.

FIG. 19. BRUCKNER REINFORCED CONCRETE CROSS-TIE, PITTSBURG & LAKE ERIE RAILROAD.

On this road the Committee inspected 5,000 Carnegie ties with the wedge fastening (for design see Vol. 10, Part 1, page 504). Mr. Gibson advised that they had no trouble with the wedges and he further said he was very much in favor of this fastening as compared with the other fastenings they have tried.

The Committee tested a number of the wedges and found practically all of them tight.

Hocking Valley Railroad:

The International Steel Tie Company, of Cleveland, Ohio, advise they have furnished 32 of their ties which were installed at Columbus, Ohio. (See Figs. 24 and 25.)

FIG. 24. INTERNATIONAL STEEL TIE, HOCKING VALLEY R. R.

Altoona & Logan Valley Railway (Altoona, Pa.):

The International Steel Tie Company, Cleveland, Ohio, advise that this company have used 550 of their ties. (See Figs. 26 and 27 for photographs of this track.)

Boston Elevated Railway:

(For previous reports see Vol. 11, Part 2, page 898, and Vol. 12, Part 1, page 387.)

Mr. A. L. Plimpton states that since making previous report they have installed the following:

1910, 71 Carnegie Ties, Sec. M-25, 14½ lbs. per ft., 7 ft. long; 1911, 1,711 Carnegie ties, Sec. M-25, 14½ lbs. per ft., 7 ft. long; 1911, 12 Lorain Steel Company ties; 1911, 614 McDonald concrete ties.

No details are given as to the design of the concrete ties.

Brooklyn Rapid Transit Company (Brooklyn Heights Railroad Company):

(See previous reports, Vol. 12, Part 1, page 388.)

Mr. C. L. Crabbs, Engineer Way and Structures, advises, September 22, 1911, as follows: "We have made no use of metal or composite ties on this System since the date of information previously furnished you, about one year ago."

Chicago City Railway:

(See previous reports, Vol. 11, Part 2, page 898; Vol. 12, Part 1, page 388.)

Mr. H. B. Fleming, Chief Engineer, says: "We have just placed an order with the Carnegie Steel Company for enough steel ties and fastenings to lay one mile of track."

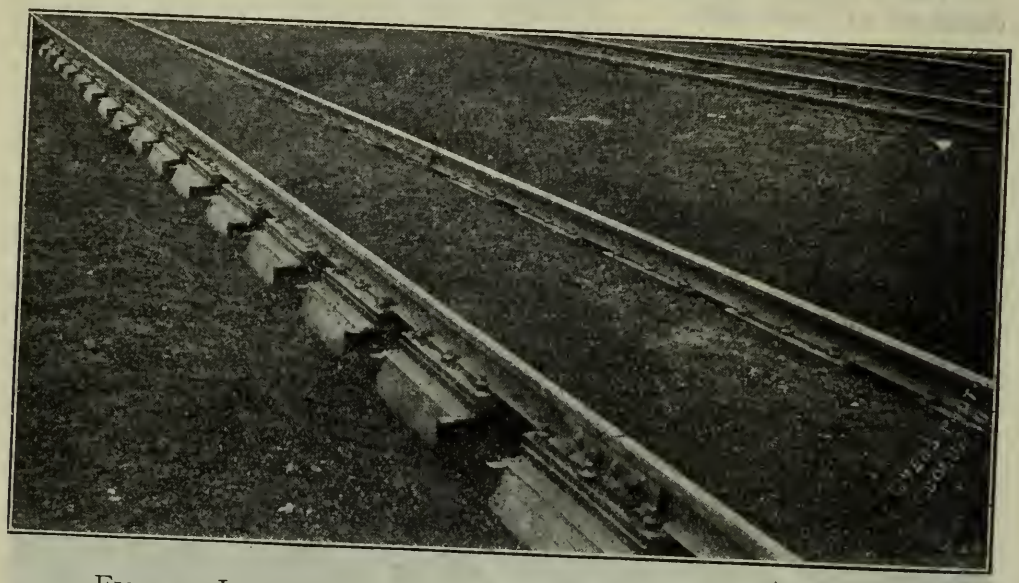


FIG. 25. INTERNATIONAL STEEL TIE, HOCKING VALLEY R. R.

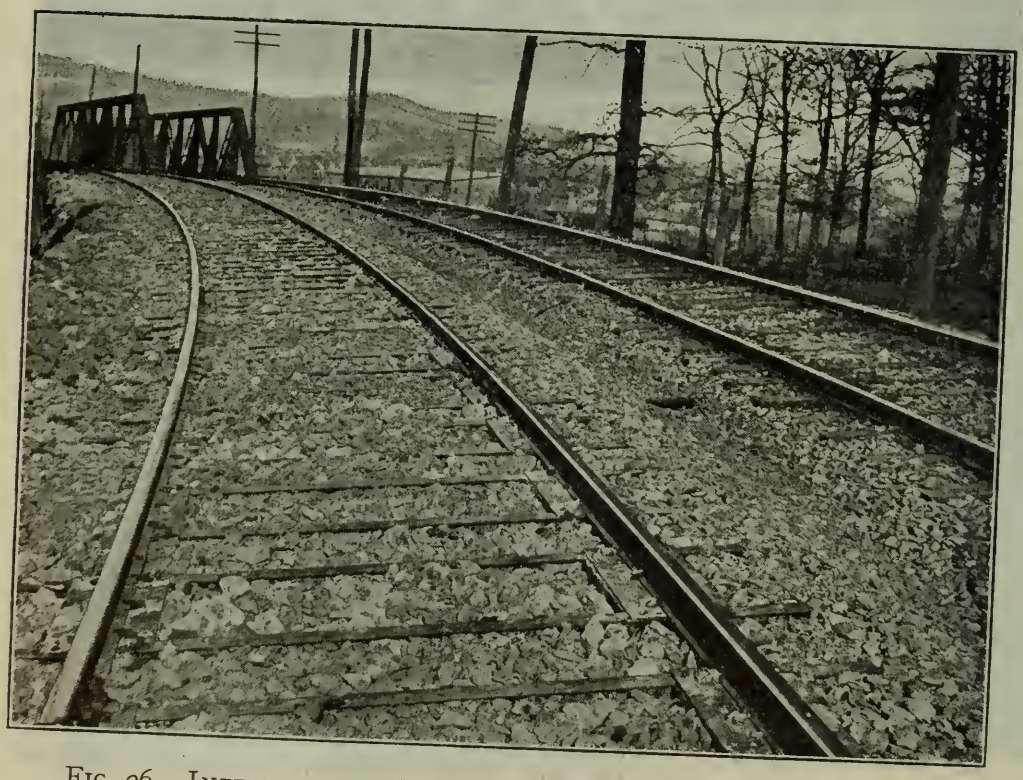


FIG. 26. INTERNATIONAL STEEL TIE, ALTOONA & LOGAN VALLEY RY.

FIG. 27. INTERNATIONAL STEEL TIE, ALTOONA & LOGAN VALLEY RY.

FIG. 29. INTERNATIONAL STEEL TIE, CLEVELAND RAILWAYS COMPANY.

Cleveland Railways Company:

The International Steel Tie Company, Cleveland, Ohio, advise that this company have used 3,300 of their ties. Photographs of this track are shown in Figs. 28 and 29.

Lake Shore Electric Railway Company (Sandusky, Ohio):

Mr. A. V. Brown, Engineer Maintenance of Way, says:

"The only ties we have installed other than hardwood and cedar ties are steel ties manufactured by the Carnegie Steel Company, known as their section M-25. We have installed about 1¼ miles of this style

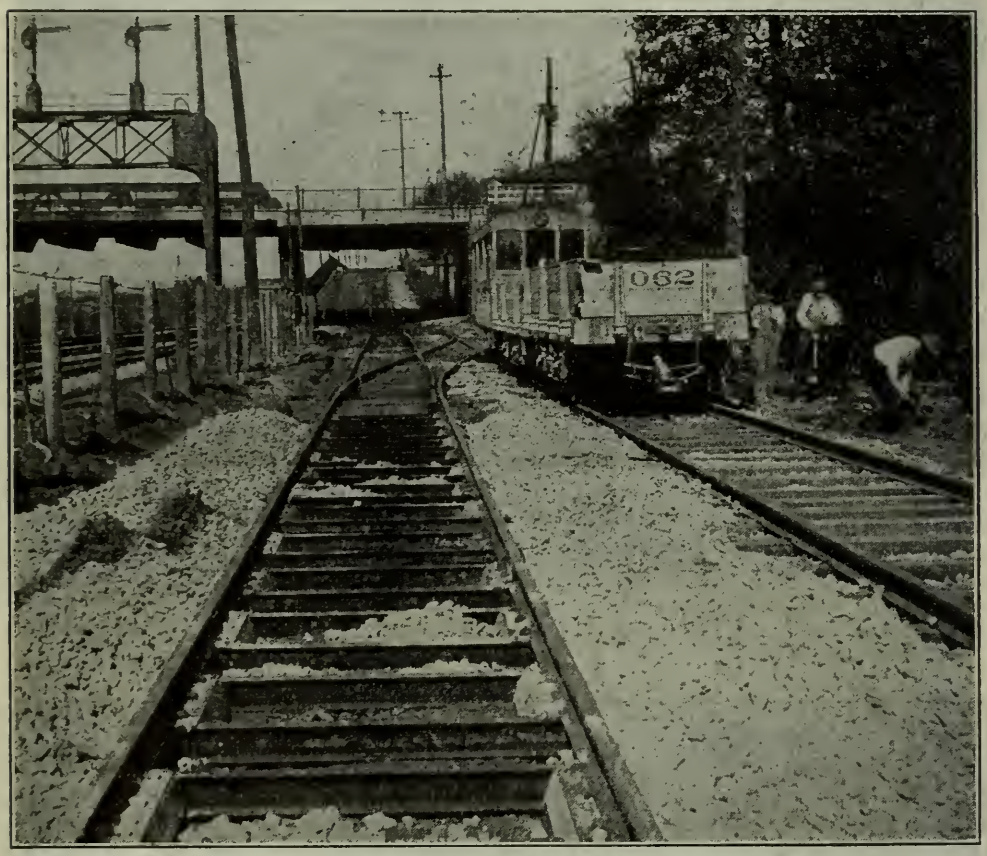


FIG. 28. INTERNATIONAL STEEL TIE, CLEVELAND RAILWAYS COMPANY.

of tie, using wide base uppermost and bolting 85-lb. A. S. C. E rail rigidly to these ties by means of their No. 25 fastening. This fastening was manufactured by the Carnegie Steel Company at our suggestion. Some of this track has been in use 11 months and up to present time has given excellent satisfaction, with no signs of deterioration.

"Six inches of concrete is used as sub-base and concrete is also placed to the top of the ties, same being tamped to place with tamping bars."

Denver City Tramway Company:

(See previous reports, Vol. 11, Part 2, page 898; Vol. 12, Part 1, page 388.)

Mr. A. M. Evans advises: "We can add no further information, nor have we made any additional installation of steel ties, nor contemplate any in the near future."

New York State Railways (Rochester, N. Y.):

Mr. B. E. Tilton, Engineer Maintenance of Way, advises:

"We have put in to date 2,035 section M-25 and 10,310 section M-24 Carnegie steel ties. These ties are all laid in concrete, 6 in. of concrete underneath the ties. No attempt has been made to lay the steel ties on stone ballast in our city lines on account of the fact that the pavement cannot be left open long enough to give the ties the necessary tamping. No steel ties have been laid on interurban lines."

Scioto Valley Traction Company (Circleville, Ohio):

The International Steel Tie Company (Cleveland, Ohio), advise that this line has used 2,200 of their ties.

Twin City Lines:

(See previous report, Vol. 11, Part 2, page 897; Vol. 12, Part 1, page 386.)

Mr. Geo. L. Wilson, Engineer Maintenance of Way, says: "This company has nothing further to report."

Utica & Mohawk Valley Railway:

(See previous reports, Vol. 11, Part 2, page 897; Vol. 12, Part 1, page 387.)

Mr. M. J. French, Engineer Maintenance of Way, advises: "We have used 713 Carnegie M-25, 7-ft. steel ties this year on North Genesee street, Utica. We have 865 of these steel ties on hand for use next year on West Dominick street, Rome, N. Y. The Oneida Railway Com-

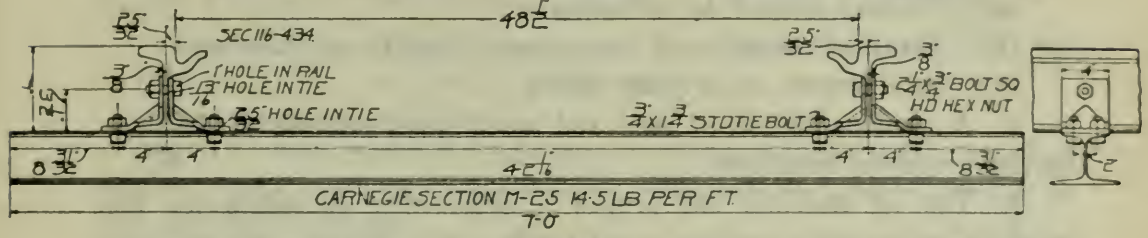


FIG. 30. CARNEGIE STEEL TIE M-25, SHOWING BRACES AND BOLTS FOR GIRDER RAILS.

pany, which is an affiliated company, under the New York State Railways control, has an order placed for 700 of these ties, for use on Madison and Sconondoa streets, in the city of Oneida, N. Y. These ties are for use with T-rail in concrete construction, the tracks to be paved with brick."

Virginia Railway & Power Company:

(For previous reports see Vol. 11, Part 2, page 898; Vol. 12, Part 1, page 387.)

Mr. T. Norman Jones, Chief Engineer, advises October 3, 1911, that they are laying two miles of track with 115-lb. 9-in. girder rail on Carnegie M-25 tie with Lorain brace fastening. (See Fig. 30.) We are using the tie inverted, in other words, with the broad base next to the rail.

CONCLUSIONS.

Your Committee respectfully submits the following conclusions:

1. The concrete tie, a combination of concrete and metal tie, or a combination of asphalt and metal tie has not yet proved a success for the following reasons:

(a) Fracture caused by vibration;

(b) Excessive weight and consequent difficulty in handling;

(c) Deterioration of asphalt filling.

2. A combination tie of steel and wood gives promise of developing an economic substitute.

3. The all steel tie has proved a satisfactory substitute for the wood tie under heavy medium speed traffic. It is durable, line and surface can be maintained, has sufficient resiliency and can be insulated. The fastenings so far in use can and no doubt will be improved.

Respectfully submitted,

COMMITTEE ON TIES.

REPORT OF COMMITTEE V—ON TRACK.

J. B. JENKINS, *Chairman;*
GEO. H. BREMNER.
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J. R. LEIGHTY.
THOMAS MANEY.
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G. J. RAY, *Vice-Chairman;*
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W. G. RAYMOND.
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F. A. SMITH.
C. H. STEIN.
F. S. STEVENS.
W. J. TOWNE.
R. A. VAN HOUTEN.
Committee.

To the Members of the American Railway Engineering Association:

Two meetings of the Committee on Track have been held since the convention of 1911—on June 15 and October 13.

The subjects assigned were:

(1) Present general specifications covering material and workmanship for frogs, crossings and switches, including the use of manganese and other special alloys.

(2) Present general specifications for track bolts, nut locks, tie-plates, common track spikes and screw spikes.

(3) Study designs for main line turnouts.

FROGS, CROSSINGS AND SWITCHES.

Your Committee has revised the plans for Nos. 8, 11 and 16 Rigid Frogs, No. 11 Spring Frog and for 11-ft., 16½-ft., 22-ft., and 33-ft. switches and submits them for adoption as general plans representing good practice.

Your Committee has also revised and combined the "General Specifications for Frogs, Crossings and Switches" adopted by the convention of 1910, and the "General Instructions for Ordering or Contracting for Frogs, Crossings and Switches," submitted to the convention of 1911 and received as information, and submits them for adoption as representing good practice.

At the convention of 1909, the Association instructed the Track Committee to recommend three standard lengths of switches and three standard numbers of frogs; such a recommendation was made, with the modifi-

cation that a fourth length of switch was added for special cases requiring frogs of large angle; the recommendation was embodied in Conclusion (4) of your Committee's report, which was adopted by the convention of 1910, but was referred back to the Committee by the Board of Direction for reconsideration.

Your Committee reconsidered and reaffirmed its former action; the conclusion was not resubmitted, however, excepting as the proposed lengths of switches and numbers of frogs were embodied in the "General Instructions for Ordering or Contracting for Frogs, Crossings and Switches" which was received only as information by the Association at the convention of 1911.

In determining the lengths of switches your Committee considered it necessary to provide for the following general classes of turnouts:

(a) Turnouts to be operated over the divergent route at the maximum practicable limited speed.

(b) Main line turnouts and crossovers to be operated over the divergent route at low speed.

(c) Yard turnouts.

(d) Turnouts requiring frogs of large angle.

The second point considered was the economical cutting of a 33-ft. rail; the question of using the full 33 ft. as one of the lengths of switch was very fully discussed by your Committee at meetings held in three successive years. The main objections to the use of a 33-ft. switch are (1) the length being the same as that of stock rail unless a special length of stock rail is used, one joint of the latter must necessarily come near the point of the switch and the other joint ahead of and near the heel of the switch, often necessitating the clipping of the angle bars, and (2) the great length of laterally unsupported rail.

Your Committee is of the opinion that (1) the location of the joints of the stock rail 40 inches ahead of the point and heel of switch is not seriously objectionable and the clipping of the angle bars is not an expensive operation and does not seriously weaken the joint, and that (2) switches 33 ft. and even 45 ft. long have been successfully used to such an extent that there seems to be little ground for apprehension on account of the length of laterally unsupported rail.

Twenty-seven (27) ft. and 30-ft. lengths have been suggested in lieu of a 33-ft. length; the angles would be respectively 22 per cent. and 10 per cent. greater than that for 33 ft.

The longest switch points are to be used in those turnouts where the highest speed is desired. These switch points will necessarily get severe usage, therefore they should be made from the very best rail. If made from the second or third rail from the top of the ingot, you have eliminated as far as possible any chance of defect in the rail. These rails are as a rule 33 ft. in length. The lengths of switches recommended can be made from 33 ft. rails without any waste.

These and other considerations led your Committee to recommend the

following length of switch points for the four general classes of turnouts named above:

(a) 33 ft.; (b) 22 ft.; (c) 16½-ft.; (d) 11 ft.

A purely theoretical investigation of the rate of turning of a locomotive at the switch point and of the angle between the stock rail and a line passing through truck centers of a car leaving the switch, indicates that an approximate balance between the deflection through the switch point and the deflection through the lead is attained when the switch angle equals one-fourth the frog angle. This proportion has been found to work out well in practice. It seems to be certain that when the switch angle exceeds one-fourth the frog angle, the switch point presents the worst feature in the alinement of the turnout and there is an economic loss both in the space occupied by the turnout and in the cost of the turnout.

With a 6¼-in. heel distance and ¼-in. thickness of point, the above relation between switch angle and frog angle would make the length of the switch in feet equal to twice the frog number.

In 1908 the frogs most used appear, from a table compiled by the Engineering News, to have been numbers 10, 7, 8, 9, 6, 15, 12, 20, 11, 14 and 16 in the order named; number 10 frogs being used by 55% of the roads tabulated and number 16 by only 5%. But the roads using No. 11's included the Chicago, Burlington & Quincy, Great Northern, Michigan Central and Northern Pacific and those using No. 16's the Baltimore & Ohio, Erie and Lake Shore & Michigan Southern.

No. 7 frogs are rapidly disappearing, being supplanted by No. 8's; the relative number of No. 10's is also diminishing, with a corresponding increase in the proportion of frogs of higher numbers.

It seems desirable for Class (A) turnouts to use the highest number of frog which is economically consistent with the longest switch point; for Class (B) the great preponderance of present practice is in favor of No. 10 frogs, but the choice of this frog would leave an unfilled gap between this and the highest number frog; besides, a No. 10 turnout with a 16½ ft. switch is little better in its worst feature than a No. 8 turnout with the same switch, while a 22-ft. switch would unduly increase the degree of lead curve; for Class (C) the trend of present practice, if not the preponderance of practice at this date, is in favor of No. 8 frogs; for Class (D) no number of frog can be specified, as this class includes a multitude of special cases.

Your Committee presents its former recommendation in a modified form:

16½-ft. switch points are recommended for frogs over No. 6 up to and including No. 10; 22-ft. points for frogs over No. 10 up to and including No. 14; 33-ft. points for frogs over No. 14 and 11-ft. points for No. 6 and under where they are required.

Nos. 8, 11 and 16 frogs are recommended as meeting all general requirements for yards, main track switches and junctions; new work should be laid out, so far as practicable, for these three frogs, so as to effect the

gradual elimination of frogs of other numbers, lessen the cost of manufacture and decrease the amount of stock carried.

TIE-PLATES AND TRACK FASTENINGS.

No attempt was made to prepare specifications, but your Committee attempted to formulate principles as to the functions, material and form of tie-plates and track fastenings. The work has not progressed far enough at this time to be embodied in a report.

DESIGNS OF MAIN LINE TURNOUTS.

The work of your Committee on this subject is necessarily held in abeyance pending the adoption of standard numbers of frogs and lengths of switches.

VERTICAL CURVES.

In order to get the benefit of experience in the use of vertical curves, a series of questions was asked members of the Association and the replies tabulated.

Under apparently like conditions, widely different results were obtained; this leads to the conclusion that the conditions were only apparently alike and that there must be other unknown conditions. The data in its present form seems to give very little information of value. Your Committee will continue its investigations.

CONCLUSIONS.

Your Committee recommends:

(1) That the "General Specifications for Frogs, Crossings and Switches" be adopted as representing good practice.

(2) That the plans of No. 8, 11 and 16 rigid frogs, No. 11 spring frog and 11 ft., 16½ ft., 22 ft. and 33 ft. switches be adopted as general plans representing good practice.

*(3) That the Committee's recommendation as to lengths of switches and numbers of frogs be adopted.

Respectfully submitted,

COMMITTEE ON TRACK.

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*For amendments, see Index.

GENERAL SPECIFICATIONS FOR FROGS, CROSSINGS AND SWITCHES.

GENERAL INSTRUCTIONS.

The Company will furnish to the manufacturer specifications and drawings. The drawings will show rail sections, splice drilling, angles, alinement, general dimensions and such details as the Company may desire.

When requested, manufacturers shall submit for approval detail drawings showing construction and dimensions of all parts to be furnished in accordance with these specifications. Conventional shading shall be used in sectional drawings. All dimensions and distances shall be shown plainly in figures. The title shall be placed in the lower right-hand corner.

The detail drawings shall be on sheets twenty-two (22) in. wide, with a border line one-half (½) in. from the top, bottom and right hand edge, and one and one-half (1½) in. from the left hand edge. The standard length of sheets shall be thirty (30) in. except that when necessary, longer sheets may be used and folded back to the standard length. Drawings of one subject only shall appear on a sheet. Scale of general drawings shall be 1½ in. = 1 ft.; details not less than 3 in. = 1 ft.

The drawings of the Company and the manufacturers' drawings approved by the Company shall be a part of the specifications. Anything which is not shown on the drawings but which is mentioned in the specifications, or vice versa, or anything not expressly set forth in either but which is reasonably implied, shall be furnished the same as if specifically shown and mentioned in both. Should anything be omitted from the drawings or specifications that is necessary for a clear understanding of the work or should any error appear in either the drawings or specifications affecting the work, it shall be the duty of the manufacturer to notify the Company and he shall not proceed with the work until instructed to do so by the Company.

INSPECTION.

Material and workmanship shall be at all times subject to inspection by a duly authorized representative of the Company, who will examine the material before it is worked in the shop. He will inspect the work during progress and will also inspect the finished product, with power to reject materials and workmanship found to be unsatisfactory. He shall have free access to the shops and mills at any and all times during the progress of the work.

The acceptance of any material by an inspector shall not prevent subsequent rejection if found defective after delivery or during the progress of the work and such defective material if furnished by the manufacturer shall be replaced by him at his own expense.

All facilities, labor and tools necessary for the shop inspection shall be furnished at the expense of the manufacturer.

When the manufacturer furnishes the rails, he shall supply the Company with a certificate of inspection made by some competent person acceptable to the Company.

MATERIAL.

Rail.

No. 1 rail, of the section ordered, as called for by the specifications, shall be used.

Fillers.

Fillers between the main and wing rails and between the main and easer rails shall be rolled steel. Throat filler blocks, not presenting a running surface, may be cast-iron.

Raiser Blocks.

Raiser blocks shall be hard cast steel.

Foot Guards.

Metallic foot guards shall be either cast-iron, malleable iron or cast steel, except that strap foot guards shall be rolled steel. Wooden foot guards shall be of best quality hard wood.

Bolts.

Bolts shall be of double refined iron or mild steel. Bolt metal shall have a tensile strength of not less than 50,000 lbs. per sq. in. and an elongation of not less than 15 per cent. in eight inches. When nicked and then broken, the fracture shall be free from flaws and unwelded seams.

Rivets.

Rivets shall be made of steel which may contain a maximum of 0.04 per cent. basic phosphorus, 0.04 per cent. acid phosphorus and 0.04 per cent. sulphur. It shall have an ultimate tensile strength of 50,000 lbs. per sq. in. It shall bend flat upon itself without fracture and when nicked and bent around a bar of the same diameter as the rivet rod it shall give a gradual break with a fine silky uniform fracture.

Reinforcing Bars.

Reinforcing bars shall be of wrought-iron or mild steel.

Plates.

Plates shall be of rolled steel.

Springs.

Springs shall be of the best quality spring steel and of dimensions and capacity shown on the plans. They shall meet the following tests:

(a) Each spring shall be placed on the testing machine and forced down solid four times.

(b) After the foregoing, each spring shall be placed on end on a flat plate, and the distance between the plate and the other end of the spring measured by means of the standard depth gage; this measurement

being the free length of the spring. The free length must conform to the plans within ⅛-in.

(c) Double springs shall be assembled and a load at least 25 per cent. greater than the rated capacity of the spring shall be applied for thirty seconds. Upon release neither spring must vary from its original free length. If either one does so vary, it shall be rejected.

(d) The inner and outer coils of springs shall be coiled in opposite directions.

Spring Covers.

Spring covers shall be made of malleable iron.

Braces.

Braces shall be made of malleable iron. forged steel.

Stops and Hold-downs.

Stops and hold-downs shall be made of mild steel.

Anti-creeping Device.

Anti-creeping device shall be made of mild steel.

Switch Lugs.

Switch lugs shall be mild steel.

Switch Rods.

Switch rods shall be mild steel.

WORKMANSHIP.

Workmanship shall be first-class. All bends shall be made accurately in arcs of circles and without injury to the material. Welding will not be permitted in any part of the frogs or in the switch rails. Planing shall be such that abutting surfaces will fit accurately together. Ends of rails shall be cut at right angles to the axis of the rail except where otherwise specified. All burrs shall be removed.

No paint, tar or other covering shall be used before inspection.

The alinement and surface of all finished work shall be even and true, and shall conform to the angles specified.

FROGS.

Fillers.

Rolled fillers shall fit the fishing angles and the web of the rail for a distance of ½-in. above and below the base and head, respectively, and shall maintain the required flangeway. Throat filler blocks shall fit the rail sufficiently well to maintain the required spacing. Where the brand of the rail interferes with the fit of the filler the brand shall be chipped off. Fillers shall be grooved or cut out to fit over rivet heads.

Heel Raiser Blocks.

Heel raiser-blocks shall fit the head, base and web of rail as provided under rolled fillers.

Foot Guards.

Solid Foot Guards shall fit the rail sufficiently well to maintain the required spacing. Strap guards shall have a minimum thickness of 3/8-in., of the width shown on plan and shall be fastened to the web of the rail by bolts or rivets not less than 3/4-in. in diameter.

Bolts.

Bolts must be round and true to size, with square heads and nuts. Threads must be accurately cut and nuts must have a wrench-tight fit. Each bolt must be provided with an approved head lock and a nut lock of approved pattern large enough to give full bearing for the nut. A 1/4-in. cotter pin shall, when required, be placed outside of and close up to the nut after it is tightened. Beveled washers must be used wherever necessary to give the head and nut a full, square bearing. Separate head lock shall be of material not less than 3/16-in. thick. Washers used under heads may be of such design as to act as head locks. Bolts must be long enough to allow the nuts to be brought out from under the head of the rail, with a suitable washer not less than 1/2-in. thick, so that the nuts may be readily tightened with an ordinary wrench.

Rivets.

The diameters of the rivets shall be of full size shown on plan, and the diameters of the rivet holes shall not be more than 1/16-in. greater than the diameters of the corresponding rivets. The rivets shall be of sufficient length to provide full, neatly made heads when driven. They shall be driven tight, bringing all adjacent parts into contact.

Rivets, when not countersunk or flattened, shall have standard button heads of uniform size for the same size rivets. The heads shall be full and neatly made and concentric with the holes. When the rivet heads are countersunk they shall be flush with the plate and fill the holes.

Reinforcing Bars.

Reinforcing bars shall fit the fishing angles and web of rail throughout their length.

Plates.

Plates shall be flat and true to surface.

Springs.

Springs shall have the ends square with the axis, so that when the spring is placed on end on a flat surface it will stand perpendicular thereto.

Spring Covers.

Spring covers shall be of such dimension as to permit a proper working of the springs and shall be provided with a spring bearing for each end of the spring.

Braces.

Braces shall fit the head and web of rail accurately.

Stops and Hold-downs.

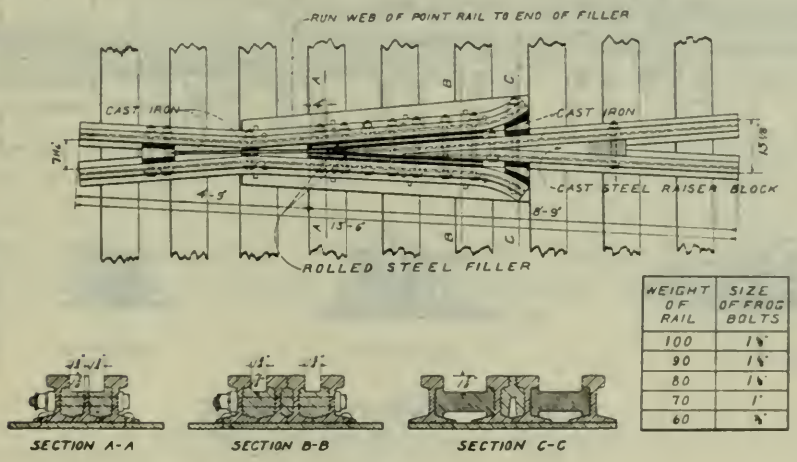
*Stops shall be so placed on plates as to hold the wing rail at 1⅞-in. opening at the ½-in. point. Hold-downs shall fit stops so as to allow at least 2 in. horizontal play and not more than ⅛-in. vertical play.

Anti-creeping Device.

The anti-creeping device shall fit accurately to the parts of the frog or angle bars.

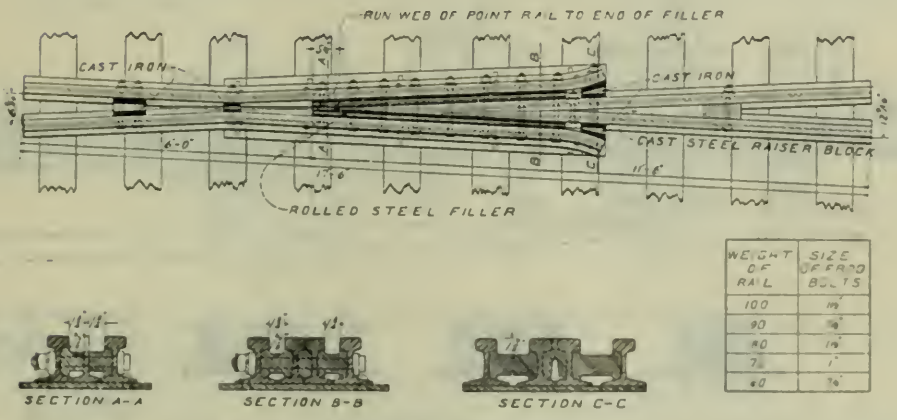
Holes for Main Bolts.

Holes shall be drilled from the solid. No punching will be permitted



WEIGHT OF RAIL	SIZE OF FROG BOLTS
100	1⅛"
90	1⅛"
80	1⅛"
70	1"
60	⅞"

NO. 8 RIGID FROG



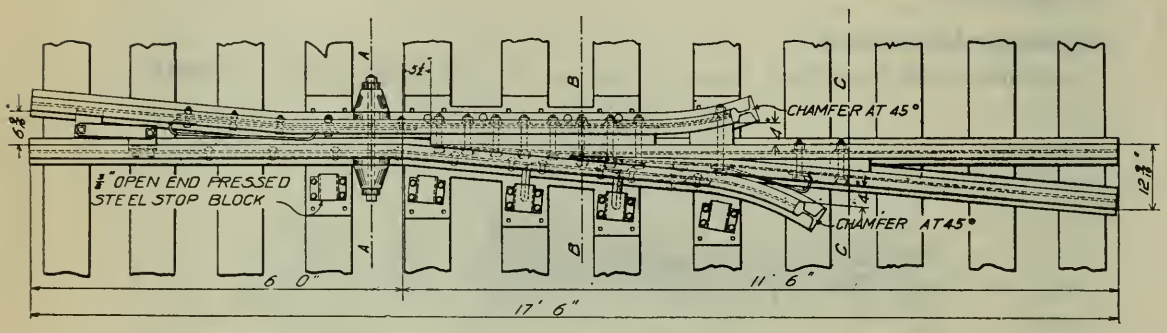
WEIGHT OF RAIL	SIZE OF FROG BOLTS
100	1⅛"
90	1⅛"
80	1⅛"
70	1"
60	⅞"

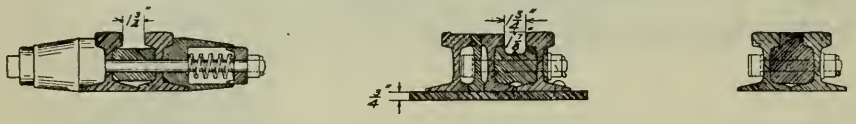
NO. 11 RIGID FROG

except of bottom plates and washers Drilling shall be accurately done, on bevel where necessary, and holes shall be made ⅛-in. less in diameter than the bolt to be used. Then the parts shall be assembled and the holes reamed so they are straight and true, with no offsets between the adjacent parts, and of such size as to give the bolts a driving fit for their entire length.

*For amendments, see Index.

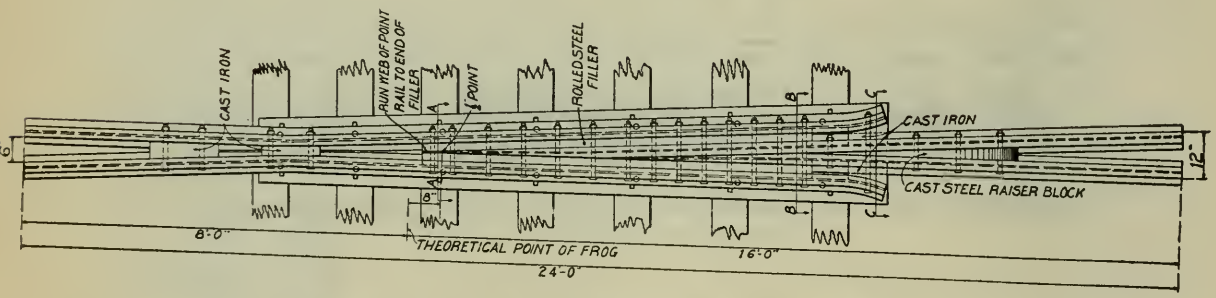
In lieu of the above specification for drilling and reaming, the manufacturer may assemble and accurately fit all the parts, before any drilling whatever is done; after the parts are securely clamped in their correct positions the holes may be drilled of such a size as to give the bolts a driving fit for their entire length.

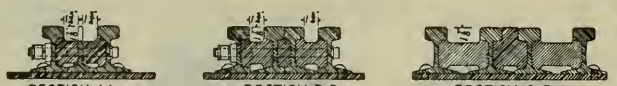




WEIGHT OF RAIL	SIZE OF FROG BOLTS
100	1⅛"
90	1⅛"
80	1⅛"
70	1"
60	⅞"

NO. 11 SPRING FROG





WEIGHT OF RAIL	SIZE OF FROG BOLTS
100	1⅛"
90	1⅛"
80	1⅛"
70	1"
60	⅞"

NO 16 RIGID FROG

Marking.

The number of the frog, maker's name, weight of rail and the date shall be plainly stamped with ¾-in. figures and letters on the flare of one wing rail for rigid frogs and the flare of both wing rails for spring frogs, or a plate shall be fastened to the frog with the same information.

SWITCHES.

Throw.

5 in. at center line of No. 1 rod.

Gage of Track.

4 ft. 8½ in.

Switch Rails.

Side planing and bending shall conform to a spread at the heel of 6¼ in. between the gage lines of the stock rail and the switch rail and a thickness of ¼-in. at the point. The bending and planing shall be done so as to give a straight gage line to the switch rail. The switch rail shall afterward be ground down to a thickness of ⅛-in. at the point, beginning 2 ft. back from the point of the switch; the point of the switch shall then be ground down to a sharp edge with a radius of 1½ in. The head of switch rail shall fit neatly against the head of stock rail from point of switch rail to point of divergence. The inner edge of the head of the stock rail and the outer face of the web of the switch rail at the point shall be in the same vertical line when the switch rail is fitted against the stock rail.

Top planing shall conform to the measurements shown on Fig. 1 and Table 1.

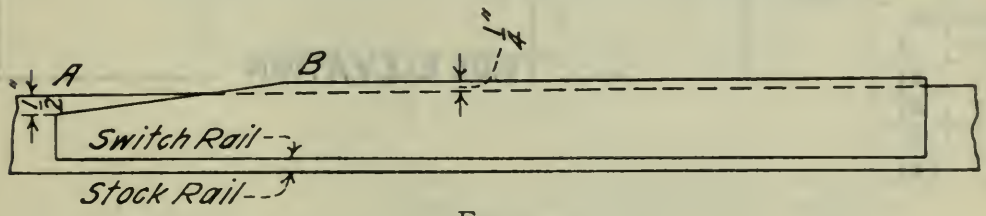


FIG. 1.

*TABLE I.

Switch.	A. B.
33 ft.	12 ft.
22 ft.	9 ft.
16 ft. 6 in.	5 ft.
11 ft.	5 ft.

Bottom of switch rail shall be planed to fit neatly on base of stock rail where bases overlap.

The point of switch rail shall be as shown by Fig. 2.

Holes for switch rod lugs and stop blocks shall be $\frac{33}{32}$-in. in diameter and 5 in. center to center. Holes for reinforcing bars shall be $\frac{33}{32}$-in. diameter. Number and location as provided under Reinforcing Bars.

Lugs.

Lugs shall be as deep as the section of rail will permit.

Distance between centers of holes for bolts running through the web of the rail shall be 5 in. Diameter of holes shall be $\frac{33}{32}$-in. Switch rod bolt hole shall be 1⅛ in. in diameter.

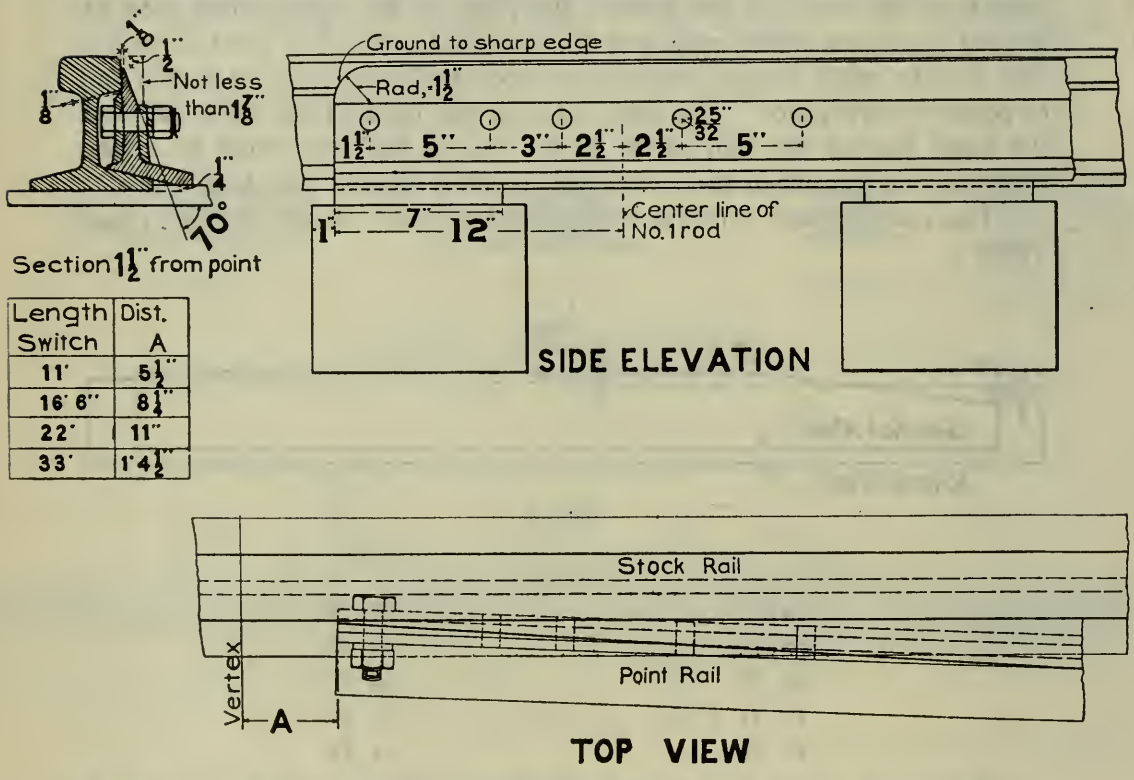
*For amendments, see Index.

Switch Rods.

Switch rods shall be ¾x2½ in. and shall be held in a horizontal plane. Bolt holes shall be 1 3/32 in. in diameter. There shall be at least 1½ in. of metal at end beyond bolt holes.

Reinforcing Bars.

A reinforcing bar ⅜-in. thick shall be riveted to each side of each switch rail and point ends shall be made flush with point of switch rail. The bars shall be as long as the heel connections will permit. Bars shall fit against web of rail and shall fill the space between head and flange of rail. There shall be ⅛-in. clearance between outer bar and head of stock rail where the bar projects under the head of stock rail. Top of inner



Length Switch	Dist. A
11'	5½"
16' 6"	8¼"
22'	11"
33'	1' 4½"

FIG. 2—DETAILS OF POINT.

bar, where it projects beyond the head of switch rail, shall not be less than 1⅞ in. below the top of stock rail. The reinforcing bar shall be beveled to an angle of 45 degrees where it projects beyond the head of the rail.

Bars shall be fastened to rail with ¾-in. rivets, bolts, except that at the first, second and fifth holes, and the holes through which the lugs are fastened, they shall be bolted. Center of first hole shall be 1½ in. from point and center of last hole in bar shall be 2 in. from heel end of bar. Intermediate rivets bolts shall be spaced so that there shall be fastenings at intervals not greater than 12 in.

Stop Blocks.

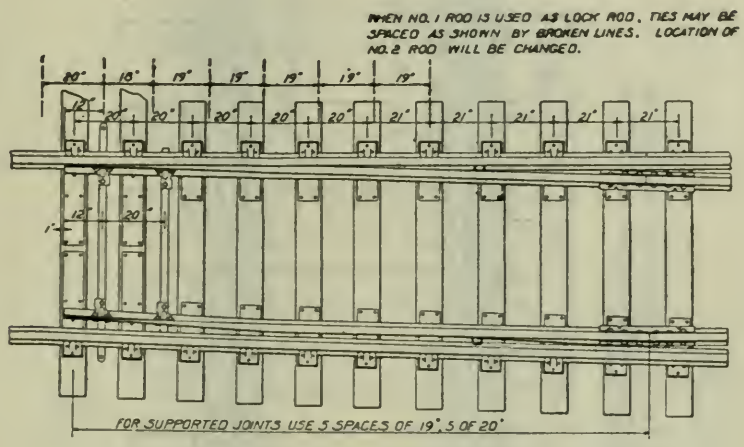
Stop blocks shall be of approved design with holes $\frac{13}{16}$-in. in diameter. Stop blocks shall be spaced as nearly as practicable at equal intervals between the end of planing and heel of switch.

Heel Blocks.

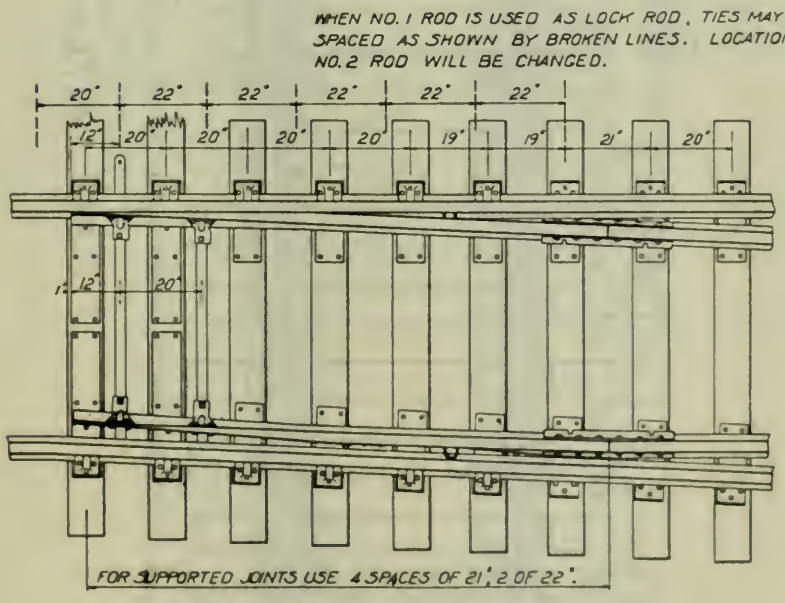
Heel blocks shall be of approved design with standard rail drilling.

Bolts and Nuts.

Bolts fastening lugs, stop blocks and foot guards to switch rails shall


WHEN NO. 1 ROD IS USED AS LOCK ROD, TIES MAY BE SPACED AS SHOWN BY BROKEN LINES. LOCATION OF NO. 2 ROD WILL BE CHANGED.
FOR SUPPORTED JOINTS USE 5 SPACES OF 19", 5 OF 20"

16' 6" SWITCH


WHEN NO. 1 ROD IS USED AS LOCK ROD, TIES MAY BE SPACED AS SHOWN BY BROKEN LINES. LOCATION OF NO. 2 ROD WILL BE CHANGED.
FOR SUPPORTED JOINTS USE 4 SPACES OF 21", 2 OF 22".

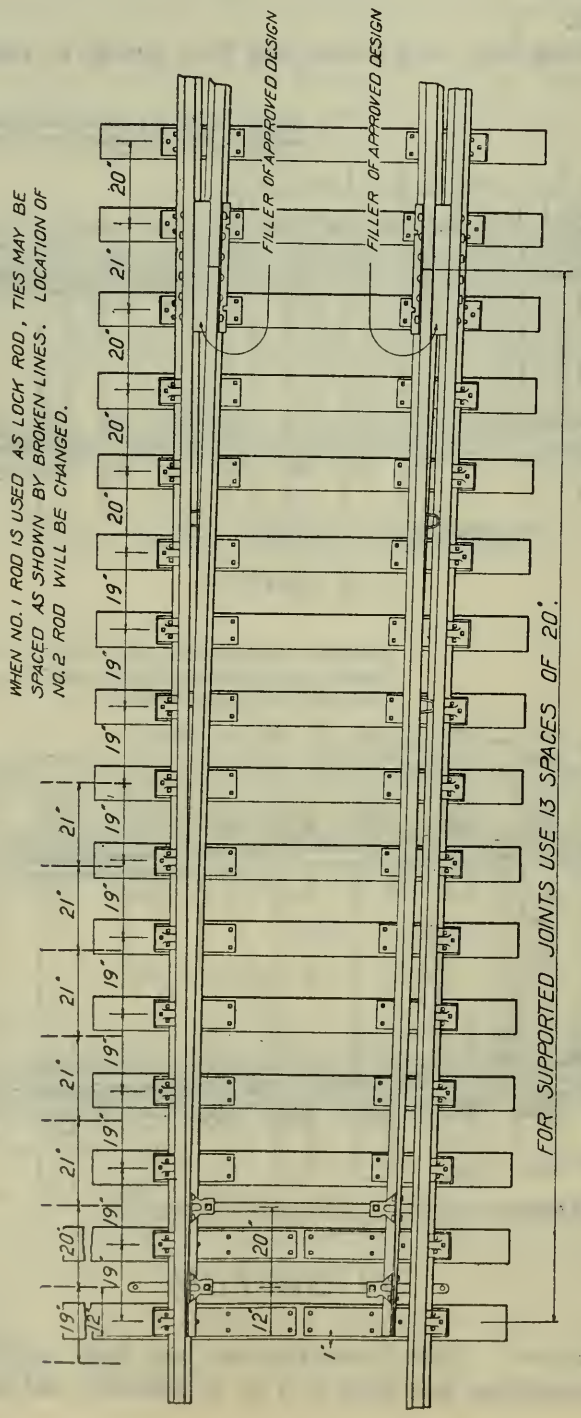
11' SWITCH

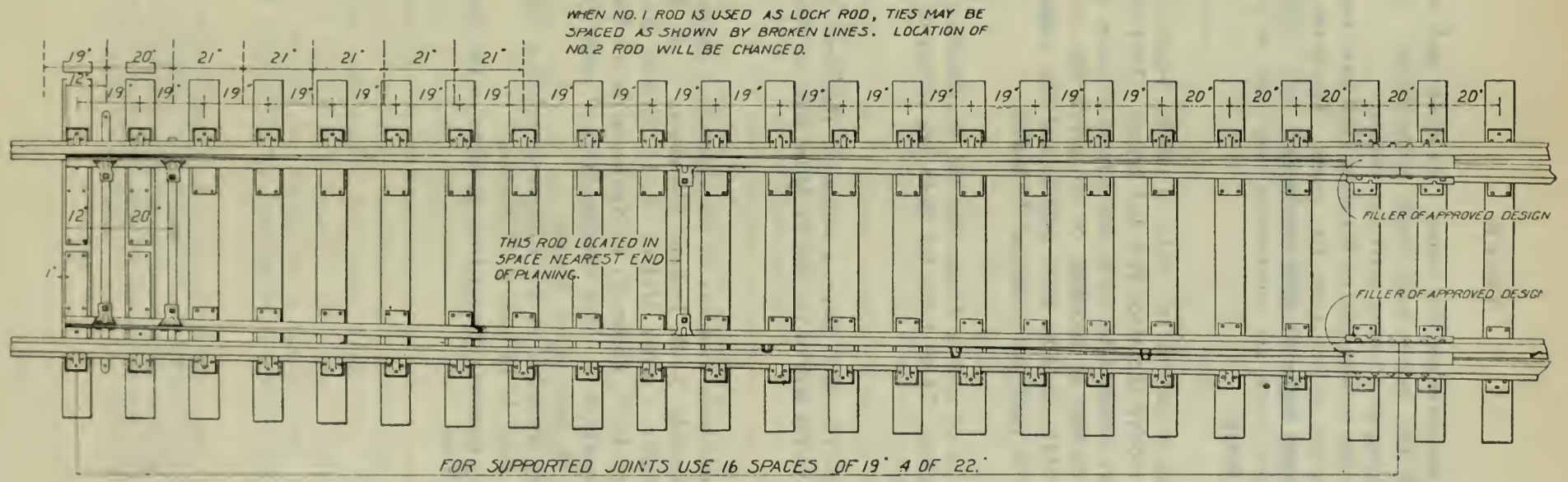
be ¾-in. in diameter. Bolts connecting the lugs with switch rods and the switch-stand connecting bolt shall be 1 in. in diameter and machine turned.

All bolts shall be provided with nut locks and cotters. ¾-in. bolts shall have hexagonal nuts and 1 in. bolts shall have square nuts.

Rivets.

The diameters of the rivets shall be of full size shown on plan, and the diameters of the rivet holes shall not be more than $\frac{1}{16}$-in. greater than


FILLER OF APPROVED DESIGN
FILLER OF APPROVED DESIGN
WHEN NO. 1 ROD IS USED AS LOCK ROD, TIES MAY BE SPACED AS SHOWN BY BROKEN LINES. LOCATION OF NO. 2 ROD WILL BE CHANGED.
FOR SUPPORTED JOINTS USE 13 SPACES OF 20".
22' SWITCH


WHEN NO. 1 ROD IS USED AS LOCK ROD, TIES MAY BE SPACED AS SHOWN BY BROKEN LINES. LOCATION OF NO. 2 ROD WILL BE CHANGED.
19" 20" 21" 21" 21" 21" 21"
12"
19" 19" 19" 19" 19" 19" 19" 19" 19" 19" 19" 19" 19" 19" 19" 19" 19" 19" 19" 20" 20" 20" 20" 20"
12" 20"
1"
THIS ROD LOCATED IN SPACE NEAREST END OF PLANING.
FILLER OF APPROVED DESIGN
FILLER OF APPROVED DESIGN
FOR SUPPORTED JOINTS USE 16 SPACES OF 19" & OF 22."

33' SWITCH

the diameters of the corresponding rivets. The rivets shall be of sufficient length to provide full, neatly made heads when driven. They shall be driven tight, bringing all adjacent parts into contact.

Rivets, when not countersunk or flattened, shall have standard button heads of uniform size for the same size rivets. The heads shall be full and neatly made and concentric with the holes.

When the rivet heads are countersunk they shall be flush with the plate and fill the holes.

Plates.

There shall be on each tie two plates of suitable length 7/8-in. by 7 in., planed down to receive the stock rail and braces. Three holes outside and two inside are required for 7/8-in. lag screws or screw spikes, or for ordinary spikes, as may be specified, on all switch ties, except the two head ties, where there shall be three outside and five inside, one of the inside holes to be in position for spiking the switch.

Braces.

Braces shall be of such a design that 2½ in. clearance for detector bars may be obtained. Three holes for 7/8-in. lag screws or screw spikes shall be provided.

Foot Guards.

Strap foot guards shall have a minimum thickness of 3/8-in. and shall be fastened to the web of the rail by 3/4-in. bolts or rivets.

Note.—The following members of the Committee approve the report as submitted herewith: J. B. Jenkins, Chairman; L. S. Rose, Garrett Davis, J. R. Leighty, Curtiss Millard, T. H. Hickey, Raffe Emerson, J. M. R. Fairbairn, H. T. Porter, P. C. Newbegin, W. G. Raymond, S. S. Roberts, F. A. Smith, R. A. Van Houten, W. J. Towne, H. R. Safford, R. M. Pearce, C. H. Stein, Thos. Maney.

The following members of the Committee approve the report conditionally; G. J. Ray, A. Bruner, F. S. Stevens.

The following members dissent from portions of the report: Geo. H. Bremner, R. O. Rote.

REPORT OF COMMITTEE I—ON ROADWAY.

J. E. WILLOUGHBY, *Chairman;*
J. R. W. AMBROSE.
JOHN C. BEYE.
D. J. BRUMLEY.
W. C. CURD.
PAUL DIDIER.
R. C. FALCONER.
S. B. FISHER.
T. H. GATLIN.
C. S. MILLARD.
W. M. DAWLEY, *Vice-Chairman;*
W. D. PENCE.
A. C. PRIME.
HIRAM J. SLIFER.
J. A. SPIELMANN.
JOHN G. SULLIVAN.
F. L. WHEATON.
W. P. WILTSEE.
R. C. YOUNG.
Committee.

To the Members of the American Railway Engineering Association:

Your Committee on Roadway respectfully submits its report to the thirteenth annual convention.

Two meetings of the full Committee were held, both at Chicago, one on June 23 and the other on November 28.

That each of the four subjects assigned to your Committee might have attention, the membership of the Committee was grouped into a like number of sub-committees.

(1) PRESENT FORMULAE OF GENERAL APPLICATION FOR DETERMINING WATERWAY AREAS UNDER VARYING CONDITIONS, WITH THE CONSIDERATION ALSO OF HYDRAULIC FEATURES.

W. D. Pence, Chairman; John C. Beye, Hiram J. Slifer, R. C. Falconer, F. L. Wheaton, Sub-Committee.

Your Committee has been considering for several years the possibility of preparing, or of selecting from the various formulæ in common use, one that can be recommended for general application. The investigation made since the Committee's report to the annual convention in March, 1909, does not warrant the Committee in varying from the opinion then expressed and accepted by the Association (see Proceedings, Vol. 10, Part 2), to-wit:

"(1) In determining the size of a given waterway, careful consideration should be given to local conditions, including flood height and flow, size and behavior of other openings in the vicinity carrying the same stream, characteristics of the channel and of the watershed area, climatic conditions, extent and character of traffic on the given line of road and probable

consequences of interruptions to same, and any other elements likely to affect the safety or economy of the culvert or opening.

"(2) (a) The practice of using a formula to assist in fixing the proper size of the waterway in a given case is warranted to the extent that the formula and the values of the terms substituted therein are known to fit local conditions.

"(b) Waterway formulæ are also used as a guide in fixing or verifying culvert areas where only general information as to the local conditions is at hand.

"(c) The use of such formulæ should not displace careful observation and the exercise of intelligent judgment on the part of the engineer.

"(d) No single waterway formula can be recommended as fitting all conditions of practice."

To the above the Committee added the following conclusions in its report to the annual convention, March, 1911 (Proceedings, Vol. 12, Part 3), to-wit:

"(1) There is a general relationship between the best-known waterway and run-off formulæ. This relationship may be expressed by two terms, a varying co-efficient and a varying exponent, substantially as shown by the accompanying diagrams, Figs. 2 and 3.

"(2) The extent of this relationship for large and small areas is indicated by the Dun waterway data, given in Table 1 and shown graphically by Fig. 1."

The Committee's work since the twelfth annual convention has been directed toward the consideration rather of the hydraulic features of the culvert, and while some progress has been made, the Committee is not prepared now to make any definite recommendation.

(2) REPORT ON UNIT PRESSURES ALLOWABLE ON ROADBEDS OF DIFFERENT MATERIALS, CONFERRING WITH THE COMMITTEE ON BALLAST.

R. C. Young, Chairman; J. R. W. Ambrose, C. S. Millard, S. B. Fisher, A. C. Prime, Sub-Committee.

The Committee has been collecting information for two years for the purpose of formulating a conclusion as to what unit pressures are allowable on the roadbed, and the Committee has come to the conclusion that since the available data treats of the sustaining power of soils below the surface, rather than of that of soils peculiarly exposed as the roadbed is to moisture, to the action of frost, and to the loadings peculiar to train service, it will be necessary to make experiments to determine the magnitude and distribution of the loads transmitted to the roadbed through ballast of various kinds and also to determine by test the bearing power of various materials under varying conditions ordinarily attained in the construction of the roadway. The Committee submits as information the following memorandum prepared by Mr. W. M. Dawley, its Vice-Chairman, after adjournment of the November, 1911, meeting:

"The safe bearing power of soils depends upon their character or composition, depth of strata, amount of water they contain or are liable to receive and the degree to which they are confined.

"Practically all of the published data in relation to the bearing power of soils is in connection with foundation work for bridges and buildings and the bearing values given are for loads applied at varying depths below the surface of the ground, hence on soils more or less well confined, and serve merely as a rough guide to the bearing power of soils other than rock when the load is applied at the surface and the soil is unconfined.

"The following table from 'Data' gives the safe bearing value in tons per square foot of soils and rock which may be placed on uniform strata of considerable thickness and well confined:

Character of Soil	Authority										
	I. O. Baker		G. B. Francis		Elmer L. Corthell			G. F. Gebhardt		W. W. Christie	
	Min.	Max.	Min.	Max.	Min.	Max.	Av.	Min.	Max.	Min.	Max.
ROCK—Granite, etc., in hard, compact strata....	200	.....	Ledge Rock	36	.....			Solid Bed Rock up to 20% of net Crushing Strength		Solid Bed Rock	200 .....
ROCK—Limestone, equal to best ashlar masonry..	25	30	.....		.....						
ROCK—Sandstone, equal to poor brick masonry..	15	20	.....		.....					.....	
ROCK—Soft and pliable as shale, equal to poor brick masonry.....	5	10	.....	.....	.....			.....		.....	
ROCK—Broken and well compacted.....	.....		.....		.....			10.0	15.0	5 to 25	
HARD PAN—Gravel and sand well cemented with clay.....	8	10	8	.....	3	12	8.7	.....	.....	.....	...
CLAY—Thick beds and dry.....	6	8	3	.....	2	8	5.08	3.0	4.0	.....	4
CLAY—Thick beds and moderately dry.....	4	6	.....		.....			2.0	.....	.....	
CLAY—Soft, wet, confined	1	2	2	.....	.....			1.0	.....	.....	1
GRAVEL—Coarse and dry, well compacted and confined.....	.....	.....	5	.....	2.4	7.75	5.1	6.0	8.0	.....	8
SAND—Dry, compact, well cemented with clay.	4	6	.....	.....	2.5	8.5	4.9	1.5	.....	.....	4
SAND—Clear and dry, confined in natural beds.	2	4	4	.....	2.25	5.8	4.5	2.0	.....	.....	2
QUICKSAND—Marshy and alluvial soils, silt, etc., confined.....	0.5	1	1	.....	1.5	6.2	2.9	0.5	.....	.....	0.5

"Elmer L. Corthell has tabulated various existing pressures of stable structures which have shown no settlement. Data were obtained from 178 separate works, in response to letter sent to prominent engineers throughout the world, requesting their experiences. The average value given, Mr. Corthell says, is low, and a safe one lies between the average and maximum. (See 'Allowable Pressures on Deep Foundations,' Corthell, 1906.)

"G. F. Gebhardt gives values which are an average of maximum loads allowed in most cities under the building laws.

"Richard Delafield, Brevet Major-General, Corps of Engineers, United States Army, member of Light House Board in 'Memoir on Foundations in Compressible Soils,' Washington, D. C., 1881, says, on page 13:

" 'The compressibility of oolitic clays can only be overcome by piling, deep sinking, heavy ramming or heavy weighting. The point of bearing must be carried below the possibility of upward reaction. The depth of a foundation in compressible ground ought not to be less than one-fourth the intended height of the building above ground; that is, for a shaft of 200 ft., the foundation should be made secure to a depth of 50 ft. by

piling or by well-sinking and concrete. (Engineer and Architectural Journal, for 1837.) Masses of concrete, brick or stone, placed on a compressible substratum, however cramped and bound, may prove unsafe. *Solidity from a considerable depth alone can be relied upon.* Mere enlargement of a base may not in itself be sufficient.

"In experiments made by Hugh Leonard (M. A.) at Akra for the purpose of testing the ordinary undisturbed alluvial soil of Calcutta, 'The results showed that for Calcutta the weight on the foundation should not be more than one ton to the superficial foot.' Journal of Royal Institute of British Architects, 1900, pp. 390-394.

"In Cunningham's Dock Engineering, page 183, speaking of foundations for masonry dock walls, it is stated that 'The maximum intensity of pressure, at any point, should not exceed a certain limit, dependent upon the nature of the ground. The safe intensity of pressure on natural foundations has been determined as follows:

On hard rock	9	to 10	tons per sq. ft.
On soft rock and hard clay	2	to 3	tons per sq. ft.
On sand and gravel	1½	to 2	tons per sq. ft.
On compact earth	1	to 1½	tons per sq. ft.
On soft, uncertain ground		½	ton per sq. ft.

"'In the case of natural foundations, care must be taken that there is no possibility of lateral escape,' and again at page 247, speaking of Lock Foundations:

"'As a general rule, hard rock and stiff clay, in which there are no springs, do not call *per se* for any artificial covering, except such as may be judged necessary to protect their surface from the softening and scouring action of water. On the other hand, alluvial deposits, sand, gravel and other incohesive strata, need the confinement afforded by a superimposed mass in addition to the lateral support of sheet-piles.

"'Earth of a porous nature, moreover, is not only unsuitable for a natural floor, but is equally undesirable as a foundation for an artificial floor, owing to its efficacy as a medium for the transmission of water pressure, on which account any covering laid upon it should be both strong and impervious.'"

Mr. Alfred C. Prime (Pennsyivania Railroad), a member of the Committee, reports as follows:

ROCK SUBGRADE

"A good quality of rock will stand up under the heaviest axle loads and under Class 'A' traffic it is sustaining axle loads on one pair of drivers of 61,500 lbs. without any signs of failure. Considering this load as distributed over two ties, gives a unit pressure of 850 lbs. a sq. ft. As stated previously the limit of bearing is unknown, but a good quality of rock will probably sustain, with proper ballast, the highest axle loads that can be placed upon it.

CLAY SUBGRADE.

"I never had any satisfaction in maintaining tracks where roadbed subgrade was composed of clay. It has always resulted in a high maintenance cost. The track will get out of line and surface and will require from one-third to one-half as much work again as where loam or sand is used. I personally believe that clay should never be used in fills on account of its high maintenance cost.

"A good grade of yellow clay will under Class 'B' traffic and axle loads of 61,500 lbs. with 6 in. of cinder ballast just sustain a pressure of about 900 lbs. per sq. ft. Speed of trains average 60 miles per hour.

SANDY LOAM.

"This has always given me satisfaction where I have used it and

had to maintain track. Under Class 'A' and 'B' traffic, speed 60-70 miles per hour with a proper depth of ballast it will maintain the heaviest axle loads that can be placed upon it. I know it is maintaining pressures of 900 lbs. per sq. ft. and how much more it is capable of sustaining is unknown.

OCEAN SAND.

"For Class 'C' traffic this is a satisfactory subgrade for loads up to 700 lbs. per sq. ft., which is about the limit of economical maintenance.

"A sand subgrade can be made to sustain Class 'B' traffic by raising track about 18 in. on engine cinders.

"All figures given above are for a single track roadway 20 ft. wide with slopes of 1½ to 1, and good drainage, with 6 in. of cinder ballast below base of tie. Tie spacing 22 in.

"The only cheap and inexpensive method for determining unit pressures on subgrades known to me, is to spread some pliable substance such as fairly thin sheet lead on top of your subgrade for a length of say 5 ft. As long as this remains straight and undeformed your allowable unit pressure on subgrade is not being exceeded, but the moment it becomes cupped and dished under the ties, the unit pressure for this class of roadbed subgrade is too high.

"In connection with this work the report of the M. W. & S. Committee on Roadbed of the Altoona Railroad Club in May, 1909, on 'Drainage of a Four-Track Railroad,' contains some interesting matter, also a paper by Mr. M. L. Byers in Bulletin of the International Railway Congress for September, 1909."

Mr. F. T. Llewellyn in December, 1898, made some tests to determine the safe load on soils at New Orleans. Pits 4 ft. x 4 ft. x 5 ft. deep, water at 18 in. below surface-bottom of pit in blue clay, wood foundation 3 ft. x 3 ft. of 3 in. x 12 in. plank doubled and crossed, with the following results:

	Load Per Sq. Ft. Lbs.	Total Load Lbs.	Settlement in Inches		
			Dec. 13-17	Dec. 19	Dec. 24
Pit No. 1	650	6100	¼	¼	5/32
Pit No. 2	1000	9280	5/16	3/8	½
Pit No. 3	1300	12000	7/8	7/16	½

Mr. O. E. Selby, Bridge Engineer, Cleveland, Cincinnati, Chicago & St. Louis Railway (see Proceedings, Vol. 8, pp. 54-59), using the formula derived by Mr. Thos. H. Johnson (see Proceedings, Vol. 7, pp. 104-105), calculates the average pressure on subgrade to be 2.4 tons per sq. ft., and the maximum to be 3.6 tons for 50,000-lb. axle loads spaced 5 ft. centers, 80-lb. rail, 7 in. x 8 in. x 8½ ft. ties spaced 20-in. centers on 12 in. of gravel ballast.

From what has preceded it will be observed that the safe bearing power of confined soft wet clay, clear dry sand confined in natural beds, quicksand, marshy and alluvial soils, silt, etc., all confined, is less than or very slightly in excess of the pressures calculated by Mr. Selby. If unconfined their bearing powers will all be somewhat reduced.

Semi-fluid soils such as quicksand, alluvium, etc., should be removed

where practicable or the foundation carried to a lower stratum, so the bearing power of such need not be considered here.

The bearing power of clay, loam, sand, etc., depends to a great extent on the amount of moisture present.

Professor Schubler of Tübingen found that 100 lbs. of dry soil would retain the following amount of water that would not flow off:

Pure Clay	70 lbs.
Clay Loam	50 lbs.
Loamy Soil	40 lbs.
Sand	25 lbs.

Drainage Farm Journal, August, 1884.

The water which destroys the bearing power of such soils may come from below by capillary attraction. The vertical capillary movement per each horizontal square foot per 24 hours being as follows:

In fine sand through 1 ft. vertical	2.37 lbs.
In fine sand through 2 ft. vertical	2.07 lbs.
In fine sand through 3 ft. vertical	1.23 lbs.
In fine sand through 4 ft. vertical	.91 lbs.
In medium clay loam through 1 ft. vertical	2.05 lbs.
In medium clay loam through 2 ft. vertical	1.62 lbs.
In medium clay loam through 3 ft. vertical	1.00 lbs.
In medium clay loam through 4 ft. vertical	.90 lbs.

See page 65, "Movements of Ground Water," by Franklin H. King and Charles S. Slichter, Government Printing Office, Washington, D. C., 1899.

If, as Professor Baker says, dry clay will sustain a load of from 6 to 8 tons per sq. ft. and soft wet clay will support but from 1 to 2 tons per sq. ft., it seems that the bearing power of clays and soils similarly affected by the presence of moisture should in each case be experimentally determined for varying percentages of moisture and such drainage arrangements made, and at such depths, as will always secure a percentage of moisture low enough to bring the bearing power up to the load it is required to carry.

BEARING POWER OF SOILS.

Composing Subgrade of Railroad Track.

(After Rankine.)

Let p = Intensity of vertical pressure on subgrade per sq. ft.

Let q = Intensity of vertical pressure at depth d, clear of superstructure, equals weight per cu. ft. of subgrade soil multiplied by depth d in feet.

Let d = Depth of soil, clear of track, the weight of which will just balance the tendency to upheaval due to the load transmitted to subgrade by the track.

Let ϕ = Angle of repose of the material composing the subgrade.

Let W = Weight of load per linear ft. of track.

Let w = Weight per cu. ft. of subgrade soil.

Let b = Breadth in ft. of track and ballast imposing load on subgrade.

The co-efficient of friction is equal to the tangent of the angle of repose, ϕ, of the soil composing the roadbed.

If two particles of earth are pressed together by a pair of equal thrusts p and p′ normal to their surface of contact, it requires a pair of equal thrusts q and q′ tangential to that surface to make them slide upon each other. For the same material, when q is just sufficient to make them slide, it is a constant fraction of p. The fraction which q must be of p just to cause slipping is the co-efficient of friction for that material. Hence, the co-efficient of friction equals q/p.

The condition of equilibrium for a mass of earth in a compound state of strain is that at every point the obliquity of the stress on the plane upon which, of all others through the point, the resultant stress is most oblique, shall itself not be greater than ϕ.

Since earth can only sustain thrusts, the principal stresses at any point will be the two thrusts, and if y be the obliquity of the resultant stress upon the plane through the point upon which the stress is most oblique, then

$$\text{Sin } y = \frac{p - q}{p + q}$$

$$\therefore \frac{p}{q} = \frac{1 + \text{Sin } y}{1 - \text{Sin } y}$$

By increasing y, the numerator of the term on the right hand side of the equation increases, while the denominator decreases, and so the ratio p/q increases. But ϕ is the greatest value of y for which equilibrium is just possible.

$$\therefore \frac{p}{q} = \frac{1 + \text{Sin } \phi}{1 - \text{Sin } \phi}$$

is the greatest ratio of p to q consistent with equilibrium; hence, the condition of equilibrium of a mass of earth is most conveniently stated thus; that at every point the ratio of the greater to the lesser principal stress shall not exceed that of $(1 + \text{Sin } \phi)$ to $(1 - \text{Sin } \phi)$.

For earth whose upper surface is horizontal, the vertical stress due to the weight and the horizontal stress are for all points the principal stresses, and their intensities are the same for all points on the same horizontal plane. Generally the vertical is the greater principal stress in any ratio not exceeding the above; whenever it exceeds the horizontal thrust by a greater ratio the earth *spreads*. But the horizontal thrust may be artificially increased till it exceeds the vertical in any ratio not exceeding the above; whenever it exceeds the vertical by a greater ratio, the earth *heaves up*.

When the earth at the side of the track is just on the point of heaving up, for points at depth d the vertical pressure p exceeds the horizontal

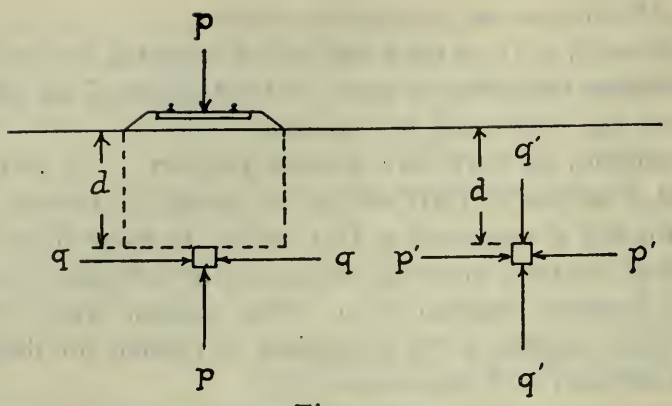


Fig. 1.

reaction q in the greatest possible amount, that earth being on the point of spreading, that is,

$$\frac{p}{q} = \frac{1 + \text{Sin } \phi}{1 - \text{Sin } \phi};$$

while for points just clear of the track, p′ exceeds q′ in the same amount, that earth being on the point of heaving up, therefore,

$$\frac{p'}{q'} = \frac{1 + \text{Sin } \phi}{1 - \text{Sin } \phi};$$

By multiplication $$\frac{pp'}{qq'} = \left(\frac{1 + \text{Sin } \phi}{1 - \text{Sin } \phi}\right)^2$$

Now p′ and q are equal horizontal thrusts on the same horizontal layer; canceling these and substituting the following values:

$$p = \frac{\text{weight per linear ft. of track and locomotive}}{\text{breadth of track and ballast}} = \frac{W}{b}$$

(q′ = weight of column of subgrade earth 1 ft. square and depth d = w d) we have

$$\frac{W}{b\,w\,d} = \left(\frac{1 + \text{Sin } \phi}{1 - \text{Sin } \phi}\right)^2$$

whence

$$d\ (\text{ft.}) = \frac{W}{w\,b}\left(\frac{1 - \text{Sin } \phi}{1 + \text{Sin } \phi}\right)^2$$

For example, assume a load of 72,000 lbs. per linear foot of track including impact on a roadbed 10 ft. wide or 3.6 tons per sq. ft. on a subgrade of dry loam weighing 95 lbs. per cu. ft. with an angle of repose of 1½ to 1 or $\phi = 33^\circ\ 42'$

$$d_{\frac{1}{2}} = \frac{72{,}000}{95 \times 10}\left(\frac{1 - .5548}{1 + .5548}\right)^2 = 6.2 \text{ ft.},$$

the depth at which a sidewise motion of the earth under the track will cease.

If the subgrade should be wet clay weighing 120 lbs. per cu. ft. with

a co-efficient of friction of .33 an angle of repose of 18°. 15′, the depth of earth required to balance the load will be

$$d = \frac{72{,}000}{120 \times 10}\left(\frac{1 - .3132}{1 + .3132}\right)^2 = 16.4 \text{ ft.}$$

If the material of subgrade has an angle of repose of 40° and weighs 120 lbs. per cu. ft. the depth will be

$$d = \frac{72{,}000}{120 \times 10}\left(\frac{1 - .6429}{1 + .6429}\right)^2 = 2.8 \text{ ft.}$$

The above analysis suggests a simple field test to determine the bearing power of soils which should be experimented with to determine its practicability.

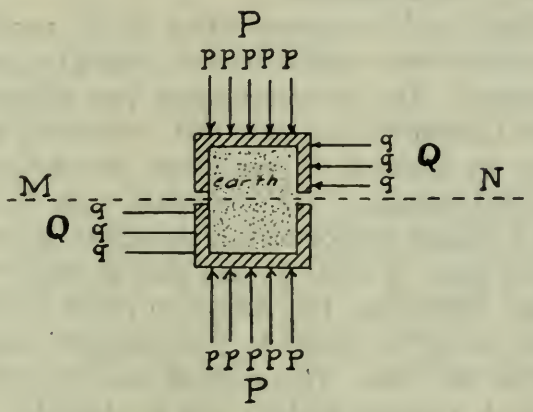


Fig. 2.

The preceding figure is a section of two troughs enclosing earth, and pressed together with a thrust of intensity p normal to MN, the plane where the troughs just approach contact, and P is the amount of this thrust. A thrust of intensity q tangential to the plane MN tends to cause the earth to slide in two parts along MN; also Q is the amount of this thrust. If Q be just sufficient to cause slipping along MN, then the co-efficient of friction of the earth is,

$$f = \frac{Q}{P} = \text{Tan } \phi$$

If a cube of the soil to be tested be enclosed in the two half boxes as indicated in the sketch and weighted down with a load P so that the intensity of pressure on the plane MN is approximately that which the soil will have to bear under the track, and the force Q which is necessary just to cause slipping along the plane MN be measured by means of a spring balance; then dividing the amount of Q by the weight of the upper half of the earth and box plus the load P will give the tangent of the angle of repose from which may be obtained the sine of the angle of re-

pose which is used in the analysis above to determine the bearing power of the soil tested.

Tests of this kind might be made, the bearing power of the soil calculated and the result compared with actual full size tests of the bearing power of the same soil and if found to agree within a reasonable limit a standard method of conducting the field test could be prescribed and the unit pressures specified for soils according to their co-efficient of friction as thus determined.

(3) REPORT ON TUNNEL CONSTRUCTION AND VENTILATION.

Paul Didier, Chairman; W. M. Dawley, J. A. Spielmann, D. J. Brumley, W. P. Wiltsee, Sub-Committee.

Your Committee made recommendation to the annual convention of 1910 as to the cross-section to which tunnels should be constructed to conform to good practice. The recommendation was adopted (Manual 1911, page 43), and the Committee has since that convention confined its attention principally to the question of ventilation. No definite conclusion has been reached, but the opinion of the Committee leans to a belief that artificial ventilation is usually unnecessary in American steam railway tunnels of less length than 2,000 to 2,500 ft., and that probably the most efficient form of artificial ventilation for American steam railway tunnels is to force air into one end of the tunnel by fans powerful enough to drive the smoke out ahead of the train. This method was adopted for the Elkhorn tunnel on Norfolk & Western Railway and is admirably described by Mr. Chas. S. Churchill in the Transactions of American Society of Civil Engineers, Vol. 54, part C. Plants similar to that constructed for the Elkhorn tunnel have been installed as shown by the record given as Appendix A. As typical single track tunnels carrying a moderate traffic, there is included in Appendix A a record as to the clearing of smoke in three single track tunnels on the Louisville & Nashville Railroad. The Committee has advice that the Baltimore & Ohio Railroad Company is now experimenting on single and double track tunnel ventilation, but the various methods used in the different tunnels are at such great variance that no conclusion has as yet been reached.

(4) REPORT ON THE QUESTION OF AGRICULTURAL DRAINAGE AS IT AFFECTS RAILWAYS.

W. C. Curd, Chairman; T. H. Gatlin, John G. Sullivan, Sub-Committee.

The Committee during the past two years collected information as to the drainage laws of the various states, but has never been able to fix upon a form into which the information can be put so as to make it of value to the Association. The Committee is of the opinion that further work along the line of collecting information as to (*a*) Laws and Assess-

ments is futile because the laws are changing constantly, and because the Committee's information is necessarily general and not subject to application to specific cases without legal advice; and further, questions affecting the laws and assessments are, in all railway organizations, handled by the railway's attorneys. The Committee recommends that it be discharged from further consideration of the subject as to Laws and Assessments.

RECOMMENDATIONS FOR 1912.

Your Committee recommends that Subjects 1, 2 and 3 be reassigned and that further consideration of subject 4 be confined to the benefits to the roadway to be derived by the construction of agricultural drainage ditches and levees.

Your Committee believes that certain additions can be made to the specifications as now printed in the Manual, for example, the sodding of slopes of cuts and fills.

Your Committee directs attention to a resolution passed at its meeting on November 28:

"Resolved, That the Board of Direction be requested to set aside an appropriation and to appoint a special committee consisting of members of the Roadway, Ballast and Track Committees, to make experiments to determine the magnitude and distribution of the load transmitted to the roadbed through ballast of various kinds and also to determine by test the bearing power of various materials under varying conditions ordinarily found in the construction of the roadway."

Respectfully submitted,

COMMITTEE ON ROADWAY.

Appendix A.

RECORD OF TUNNEL VENTILATION.

Under Plans of Chas. S. Churchill and C. C. Wentworth.

Location of Tunnel	Date of Installation	Rate of Grade	Location of Fans	Length of Tunnel, Ft.	Section Sq. Ft.	Contents Cu. Ft.	Cu. Ft. Air delivered per min. through Tunnel	Remarks
N. & W. Ry. Elkhorn, Coaldale, W. Va	6-01	+1.4%E	Lower End	3000	ST235	705000	400000	Train ton rating inc. in 1901, 100 tons.
C. & O. Ry. Big Bend, E. Hinton, W. Va	12-02	⅔ Lgth +0.4%E	Upper End	6500	ST250	1625000	300000	Train ton rating inc. 228 tons.
P. R. R. Gallitzin, W. Altoona, Pa	4-05	+0.5% W	Lower End	3600	ST324	1166400	502000	
P. R. R. Washington, D. C., Station	12-07	+0.13%S	Upper End	Tubes 4050 Sta. 760	1 tube 260 2-6 tracks	3371800	640000	2 tubes, 520 sq. ft. Station end variable.
P. R. R. North and East Rivers, N. Y	9-10	Special vent. of	installat tubes th	ion 14 fa at are 41	ns for e 35 ft. to 225	mergen 7357 ft.	cy uses 40000 to 111000	
B. & O. R. R. Kingwood Tunnelton, W. Va	12-10	+1.0%E	Lower End	4138	ST352	1458000	600000	Train ton rating inc. 450 tons.
C. & O. Ry. Lewis, Alleghany, Va.	6-11	+1.14% W	Lower End	4026	ST318	1280200	508800	
N. Y. C. Lines Weehawken, N. J	8-11	+0.25%E	Lower End	4365	DT469	2047200	512000	144 trains per day.
P. R. R. B. & P. Tunnel, Baltimore, Md	9-11	+1.32%S	Upper End	4963	DT432	2150000	500000	193 trains per day.

Letter of R. C. Morrison, Superintendent, Louisville & Nashville Railroad.

There has never been any trouble to trainmen from smoke in either Dossett or Solway tunnels, excepting in one instance; about three months ago an engineer on the second engine of a heavily loaded double-headed freight train claims to have been overcome by the gases while passing through Solway tunnel. We did not consider this claim very seriously.

It was evidently a strike on the part of the engineer against double-heading.

In clear weather after No. 32 passes through these tunnels if no firing is done immediately before entering the tunnels or during the passage through the tunnels, it leaves the tunnel practically clear, whereas after a southbound freight train it takes from ten to fifteen minutes for the tunnels to clear sufficiently to see through them.

Damp weather affects the clearing of these tunnels very much. In fact, during very damp weather, doing an ordinary business Dossett tunnel never gets entirely clear. This does not apply so much in the case of Solway tunnel, as this tunnel seems to clear itself better of smoke than any tunnel I have ever known, considering the length.

We keep our trains ten minutes apart passing through both of these tunnels, both tunnels being protected by electric blocks. I am inclined to believe that the smoke in both of these tunnels comes out from the far end in the direction the train is moving, that is, when a train passes through the tunnel, it starts up a current of air that seems to continue after the train has passed and has a tendency to draw the smoke through the tunnel after the train.

During our heaviest business we have never been bothered with delay to traffic on account of smoke in either of these tunnels.

We have no established rules or instructions governing the method of firing while passing through tunnels. It is customary on heavily loaded freight trains, southbound, to put in a heavy fire going into either of these tunnels. It is very seldom necessary while passing through Dossett tunnel, but, on heavily loaded freight trains, they do have to put in a fire once and sometimes twice while in Solway tunnel.

For the first two weeks in October, average number of trains passing through these tunnels per 24 hours was 23. Our business, however, is a little light. I think I would be safe in saying that we could successfully operate fifty trains per day through these tunnels without the air becoming so foul as to delay traffic.

Length of Dossett tunnel 3,520 ft., single track. Grade 0.50 per cent. rising to south. Train 32 is northbound limited train.

Length of Solway tunnel 2,170 ft., single track. Grade 0.50 per cent. rising to south. The construction shafts in both tunnels were closed.

Letter of E. E. Snyder, Superintendent, Louisville & Nashville Railroad.

Muldraugh tunnel is on an ascending grade to the south of 70.3 ft. per mile. We regard the tunnel as a quick clearing one from smoke and gases. The hardest feature is on a southbound double-heading train when the crew of the second engine gets a good dose. All southbound full tonnage trains and our through passenger trains are double-headed, helping engine in front.

There is a little smoke and gas after a northbound freight train but not a great deal as the trains roll and there is but little exhaust. North-

bound passenger trains do not work steam through the tunnel. The helping engine always goes through the tunnel and is cut off at Tunnel Hill. We have about 40 train movements, divided one-half north and one-half south, per day, not including the return movement of the helping engine.

LETTER OF J. F. BURNS, ROADMASTER, LOUISVILLE & NASHVILLE RAILROAD.

In regard to smoke in Muldraugh's tunnel, M. S. First Division. I attach a statement showing the action of the smoke after passage of southbound trains on the 7th inst. (October 7, 1911), from which it appears that trains are from one minute to two minutes in going through the tunnel and the tunnel is clear of smoke in from seven to twelve minutes. It so happened that the smoke was longest in clearing after passenger train 5 with a K1 engine, and the shortest time was with a double-heading freight train. I consider this tunnel as very quick clearing. As trains are never closer together than fifteen minutes in the tunnel, one train never has disadvantage from the smoke of a preceding train.

ACTION OF SMOKE IN MULDRAUGH'S TUNNEL.

Main Stem First Division After Passage of Southbound Trains on 7th of October, 1911.

No. of Train	Engine	Time Train Going Through Tunnel	Time After Engine Got Through Tunnel Until Clear of Smoke
73	1112 and 848	2 minutes	7 minutes
2nd 73	1107 and 848	2 minutes	8 minutes
31	881	1½ minutes	9 minutes
5 Passenger	153	1 minute	12 minutes
2nd 5	124 and 849	1 minute	11 minutes
17	731 and 849	1½ minutes	9 minutes
75	1176 and 849	2 minutes	10 minutes
2nd 75	709 and 848	1½ minutes	8 minutes

REPORT OF COMMITTEE XIII—ON WATER SERVICE.

ROBERT FERRIDAY, *Chairman;*	J. L. CAMPBELL, *Vice-Chairman;*
JAMES BURKE.	E. G. LANE.
H. M. CHURCH.	G. C. MILLETT.
C. C. COOK.	A. MORDECAI.
G. M. DAVIDSON.	W. A. PARKER.
A. F. DORLEY.	C. L. RANSOM.
G. H. HERROLD.	CHAS. E. THOMAS.

Committee.

To the Members of the American Railway Engineering Association:

The Board of Direction assigned the following subjects to your Committee:

(1) Report on the design and relative economy of track pans from an operating standpoint.

(2) Present typical plans and specifications for tank supports.

(3) Report on the use of reinforced concrete for water tanks and supports.

Three meetings were held, all of them in the Secretary's office: June 21, August 28, October 30, 1911.

It was decided, since the subject of "Water Tanks," including supports, had been under consideration so long, to request the Board to drop subject No. 2 and substitute "Deep Well Pumps," approval of which was given later.

A Sub-Committee on Water Treatment was appointed with the idea that your Committee should have such a sub-committee every year whose duties would be to keep informed of the progress in this subject, and make reports as seemed desirable. The Board was asked to request G. M. Davidson to become a member of your Committee, and he was appointed chairman of this sub-committee pending such arrangement.

Sub-Committee A met at Painesville, Ohio, August 19, and the filling, heating and drainage systems of the Lake Shore & Michigan Southern Railway track pan installation at that point was explained by Mr. M. U. Baillierre, Assistant Engineer, who had charge of the construction of the track pans, plans of which were included in the 1911 Proceedings.

Sub-Committee B met in the Secretary's office August 4 and December 9.

The subjects in the hands of your Committee stand as follows:

REVISION OF THE MANUAL.

No changes to recommend until the Association decides on the future policy now under consideration.

(1) THE DESIGN AND RELATIVE ECONOMY OF TRACK PANS FROM AN OPERATING STANDPOINT.

Report progress. No further report is made for the reason that such additional data as can be secured is from elaborate tests made by the Pennsylvania Railroad at Atglen, Pa., which are not yet available. Your Committee also hope to secure report prepared for a Special Committee of the New York Central Lines by G. W. Vaughan, Engineer Maintenance of Way of that railway.

(2) DEEP WELL PUMPS.

Report progress. This subject has not been developed sufficiently to report otherwise.

(3) USE OF REINFORCED CONCRETE FOR WATER TANKS AND SUPPORTS.

Complete report is hereinafter submitted with the request that it be received as information.

(4) WATER TREATMENT.

Report progress.

In view of the brevity of its report, your Committee desires to submit in Appendix "A," for the information of the Association, a paper prepared at its request by J. R. Francis, regarding an unusual occurrence of locomotive boiler corrosion which followed a partial installation of water softeners. It is quite possible the same trouble may be experienced by our members under similar conditions, and information regarding the means for overcoming it will be of value.

Your Committee also have canvassed the membership for opinions and criticism of the General Specifications for Steel Tanks submitted last year, and same have been revised and are submitted with the recommendation that they be adopted and published in the Manual.

THE USE OF REINFORCED CONCRETE FOR RAILWAY WATER TANKS AND SUPPORTS.

As part of its work for the year 1910, the Water Service Committee was directed by the Association to prepare plans and specifications for a reinforced concrete water tank. The result of the Committee's work is published as information in the 1911 Proceedings.

For the year 1911, the Committee is directed to report on the use of reinforced concrete for water tanks and supports.

Many reinforced concrete tanks have been built in America and Europe ranging in capacity from 10,000 gals. to more than 1,000,000 gals. each. Published descriptions of a large number of these can be found by reference to the Engineering Index. A list of about 50 of them is published on page 124 of the Engineering News of July 27, 1911.

In connection with the construction of a new concentrator, the Mactezuma Copper Company, Nacozari, Sonora, Mexico, built 128 reinforced concrete tanks of 10,000 gals. capacity each for water and concentrates.

They are water-tight except a little sweating around a few of the pipe connections in the tank bottom. These tanks are 12 ft. in diameter and 12 ft. high. The form was erected complete and each tank was poured in one operation, thereby eliminating joints in the shell, which is 6 in. thick. The bottom is 12 in. thick. A very rich concrete was used. All of the stone would pass through a screen having ¼-in. mesh. The steel in the shell is stressed 11,400 lbs. per sq. in., not considering the tensile strength of the concrete. At the bottom of the tank the concrete in the shell is stressed only 63 lbs. per sq. in. without assistance from the steel. The concrete in these tanks can carry that stress without breaking. Consequently, the stress is doubtless divided between the steel and the concrete and the unit stress must be very low. The vertical reinforcement of the shell consists of ¼-in. rods spaced 12 in. c. to c.

Reinforced concrete tanks have been built either as standpipes or as elevated tanks on concrete towers.

The advantages are:

(1) Low maintenance cost.

(2) Great durability.

This may be true only of well-designed, well-built and water-tight tanks.

The disadvantages are:

(1) Innovation in railway service.

(2) Imperfections in materials and workmanship.

(3) Greater first cost.

(4) Porosity of the concrete.

(5) Shrinkage of the concrete.

(6) Stretch of the concrete.

(7) Difficulty of waterproofing.

(8) Effect of frost on saturated concrete.

(9) Ugliness.

(10) Immovability.

No. 1 will be removed in time if the concrete tank develops sufficient merit.

No. 2 is more incidental than fundamental, but the making of a strictly uniform high-grade monolithic concrete construction without local imperfections is difficult and requires highly efficient workmanship.

No. 3 may be justified by the advantages named. It can be shown in some cases that a reinforced concrete tank costs less than a steel tank of like capacity, but in such cases the design is probably sparing in the use of steel and concrete. A thin shell and a high stress in the steel are liable to result in a leaky tank. Generally, when the stress in the steel is low enough and the tank shell thick enough to insure against leakage, the cost of a reinforced concrete tank will be greater than that of a steel tank.

No. 4 is the root of much of the trouble with the concrete tank. It is not an insurmountable difficulty. Careful selection and grading of sand and stone, liberal use of cement, complete and uniform mixing and proper placing will make a concrete impervious under the pressures required for railway water service. Serious leaks will be due to local

imperfections rather than to porosity if the tank has been well-designed and constructed of a proper grade of concrete.

No. 5 is a more fundamental difficulty. Shrinkage of concrete in setting is inevitable and it is increased by the large proportion of cement required in water tank construction. This frequently produces cracks, especially along the joints between successive courses of concrete. Careful and proper making of the joints and judicious steel reinforcement are necessary to prevent serious shrinkage cracks. The steel dam mentioned in the accompanying general specifications is a desirable thing in the joints when the concrete in the first half of the joint has hardened before the concrete in the second half is placed.

No. 6 is a serious difficulty in the shell of the tank due to elasticity of the steel reinforcement and its stretch under the water load. Any concrete, however dense and impervious in its unstrained condition, can be stretched beyond its breaking strength and fine cracks through which water will flow under pressure may be opened therein by stressing the steel within the elastic limit of the latter. If the tank could be maintained constantly full of water the moderate leakage due to such stretch would generally stop through deposits of suspended matter from the filtering water. In some cases this would be assisted by chemical precipitation. But, under general service conditions there is a wide fluctuation of pressure and the elastic recovery of the steel as the pressure drops appears to break down the plugging action of the leakage above indicated in those cases where the steel is stretched materially beyond the breaking point of the concrete.

Herein appears to lie a formidable handicap of the concrete tank as a competitor of the steel tank on the basis of cost. The effectual remedy appears to be the combination of that low stress in the steel with that increased thickness of the shell which will limit the stretch of the concrete so that cracks permitting the filtration of water will not be opened. That increases the cost of concrete and steel, making the latter approach the cost of steel in a steel tank.

Your Committee is of the opinion that the ultimate stress of the steel without assistance from the tensile strength of the concrete should not exceed 10,000 lbs. per sq. in., and that the minimum thickness in inches of the concrete at any point should be such that when the total tensile stress due to water load at that point is diminished by 3,000 times the sectional area in sq. in. of the steel at that point, the remaining water load will stress the concrete at that point 300 lbs. per sq. in., provided that in no case shall the thickness of concrete be less than 4 in. Your Committee does not say that concrete will not break under a tensile stress of 300 lbs. per sq. in., although experiments indicate that concrete of the high grade required for tank construction may have an ultimate tensile strength of 400 to 500 lbs. per sq. in.

This specification as to thickness of concrete is an arbitrary one intended to secure a minimum and reasonable thickness somewhat in excess of the thickness of concrete in tanks already constructed in which the stress in the steel has been 12,000 lbs. or more per sq. in., resulting in some leakage. The primary object is to secure a minimum thickness of

wall in which tension cracks, if any, will be localized and minute and through which it would be difficult for water to pass. The size and the arrangement of the reinforcing rods have an important bearing on the minimum permissible thickness of concrete. The shrinkage of the concrete around large rods in a thin wall is liable to crack the concrete.

The trouble from stretch of the concrete raises the question as to the practicability of designing a tank shell to be in compression. This could be accomplished by building the shell as a series of short, flat, abutting arches convex to the center of the tank with the reinforcing steel supported by exterior pilasters forming the abutments of the arches, as indicated in the suggested plan and elevation of a section of concrete tank shell designed to be in compression appearing on the accompanying drawing, showing a general plan and general section for a suggested concrete standpipe. The radius of the arches may readily be proportioned to make the total compression in the concrete equal to the total tension in the steel. The reinforcing rods between the pilasters may be covered by metal lath and cement plaster. The density and imperviousness of the concrete in the arches would be increased by the water load. The polygonal form of the tank with its recessed panels would break the monotony of a plain cylinder and give the tank an improved appearance. Doubtless difficulties would arise in the execution of such a design, but without going into details, the suggestion is offered for what it is worth.

No. 7 arises from 4, 5 and 6. The problem is to find some foreign substance which, when incorporated with the concrete, will close the percentage of voids found even in the best grade of concrete, or, when applied to the surface, will be impervious and will not crack or peel off. In either case the trouble is aggravated and the waterproofing largely nullified by the shrinking and stretching of the concrete unless the latter is properly reinforced against shrinkage and stretch. Tanks in service prove that it is practicable to make concrete impervious under ordinary tank pressures by proper selection, grading and mixing of materials. Soap and alum incorporated with the concrete in the making and applied as washes to the surface are probably the best proved and most efficient materials for effective waterproofing of concrete.

No. 8 is a danger which will be eliminated by successful solution of waterproofing. Since the latter will require as its base a very dense concrete, the quantity of water passing through the latter will be so small that the action of frost can have little or no effect on such close grained and practically dry concrete. It is a fact, however, that in our northern latitudes much disintegration of porous concrete on the water line of lakes and streams due to the annual effect of the frost season is apparent.

Ugliness is a sin chargeable to some railway structures other than water tanks. Perhaps a little additional homeliness is not unpardonable if saved by the grace of utility. Monolithic concrete, especially a form-marked, joint-marked, leaky efflorescent tank shell possesses a lack of beauty which is not hidden by frills. The attainment of a water-tight tank requires a high grade of material and work which will go far toward making concrete tanks presentable in appearance.

An irremovable objection to the concrete tank is its immovability. A wooden tank and even a steel tank can be and such tanks are moved from place to place to meet changing requirements of railway water supply. Discovery of new and better water supplies sometimes makes changes in locations of tanks desirable. A concrete tank should be located only at those points where there is no probability of change.

Considering the obvious merits of the concrete tank, this Committee sees no reason why railways engaged in permanent reconstructions for fixed water supplies should not favorably consider a beginning in reinforced concrete tank construction. Water-tightness is the important problem. The stability of this form of construction is well established.

Many existing concrete tanks are practically water-tight. Generally, leakage is immaterial in amount and objectionable principally as a matter of appearance and a possible danger account of frost. It is more often the result of local imperfections, bad joints, and a thin shell and a high stress in the steel than porosity and permeability in a proper grade of concrete.

Your Committee submits as information:

(1) General Specifications for Reinforced Concrete Standpipe Water Tanks for Railways. No plans of tank are submitted with these specifications.

(2) Suggestive sketches consisting of:

An elevation and section of reinforced concrete standpipe tank.

A section through valve box in the foundation.

A plan and elevation for reinforced concrete tank shell designed to be in compression.

An elevation and section of reinforced concrete tank on a reinforced concrete substructure.

A plan, elevation and section of reinforced concrete substructure.

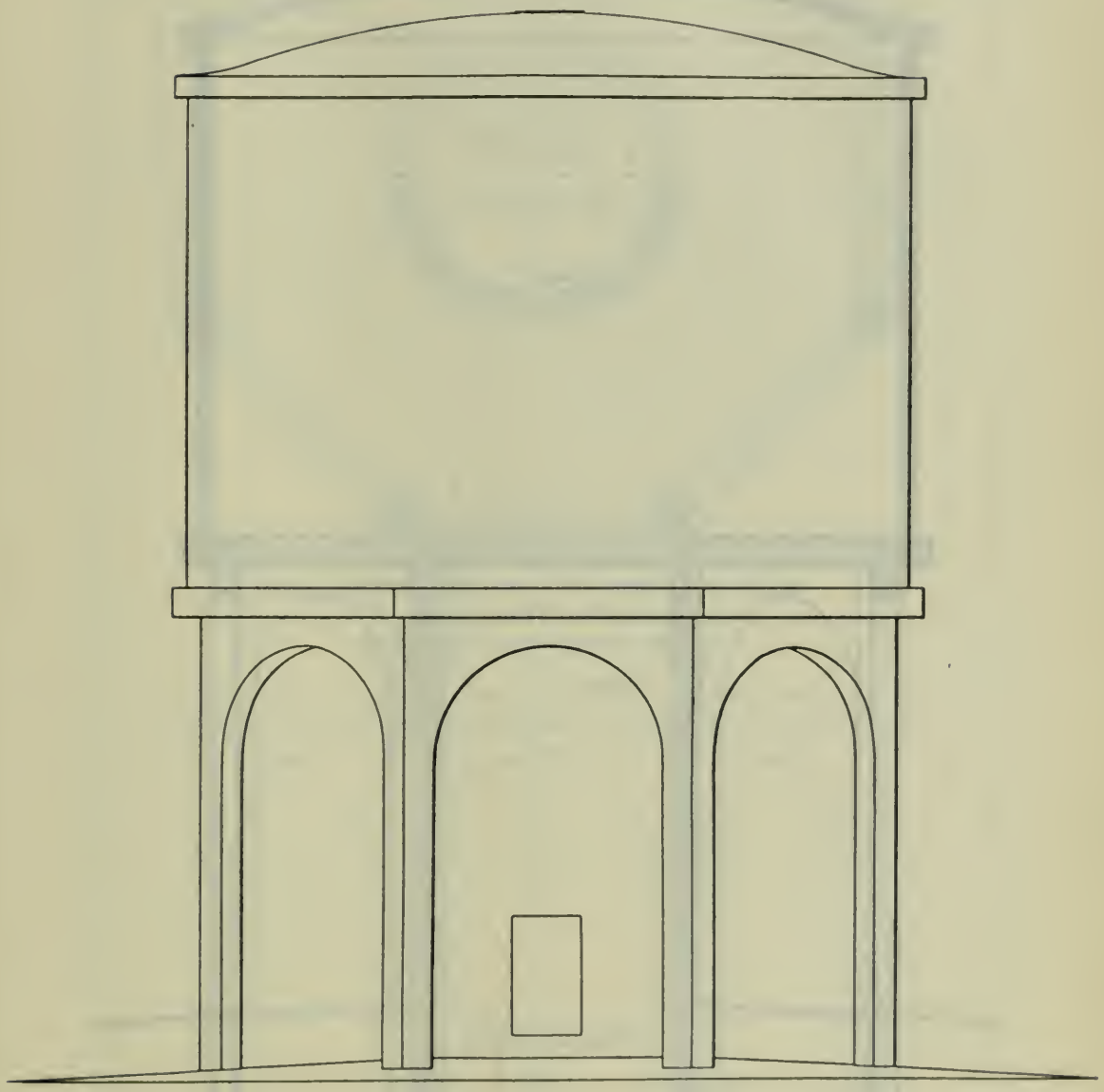
The tank should be located away from the main line track and should deliver water to engines through water columns.

If a roof is required, it should be built as shown. Where ice will not form to an injurious or troublesome extent and sunlight will not cause vegetable growth in the water, the roof may be omitted.

For a given amount of available storage and considering piping, frost-proofing, and collection and disposal of sludge, the standpipe is simpler and more economical than a tank on a tower, notwithstanding it is practicable to erect a concrete tower 20 ft. high including foundation at an expense less than the cost of the foundation and lower 20 ft. of a concrete standpipe. This refers to railway service. For quantities of water required only at higher elevations, the concrete tower may readily be more economical than the standpipe.

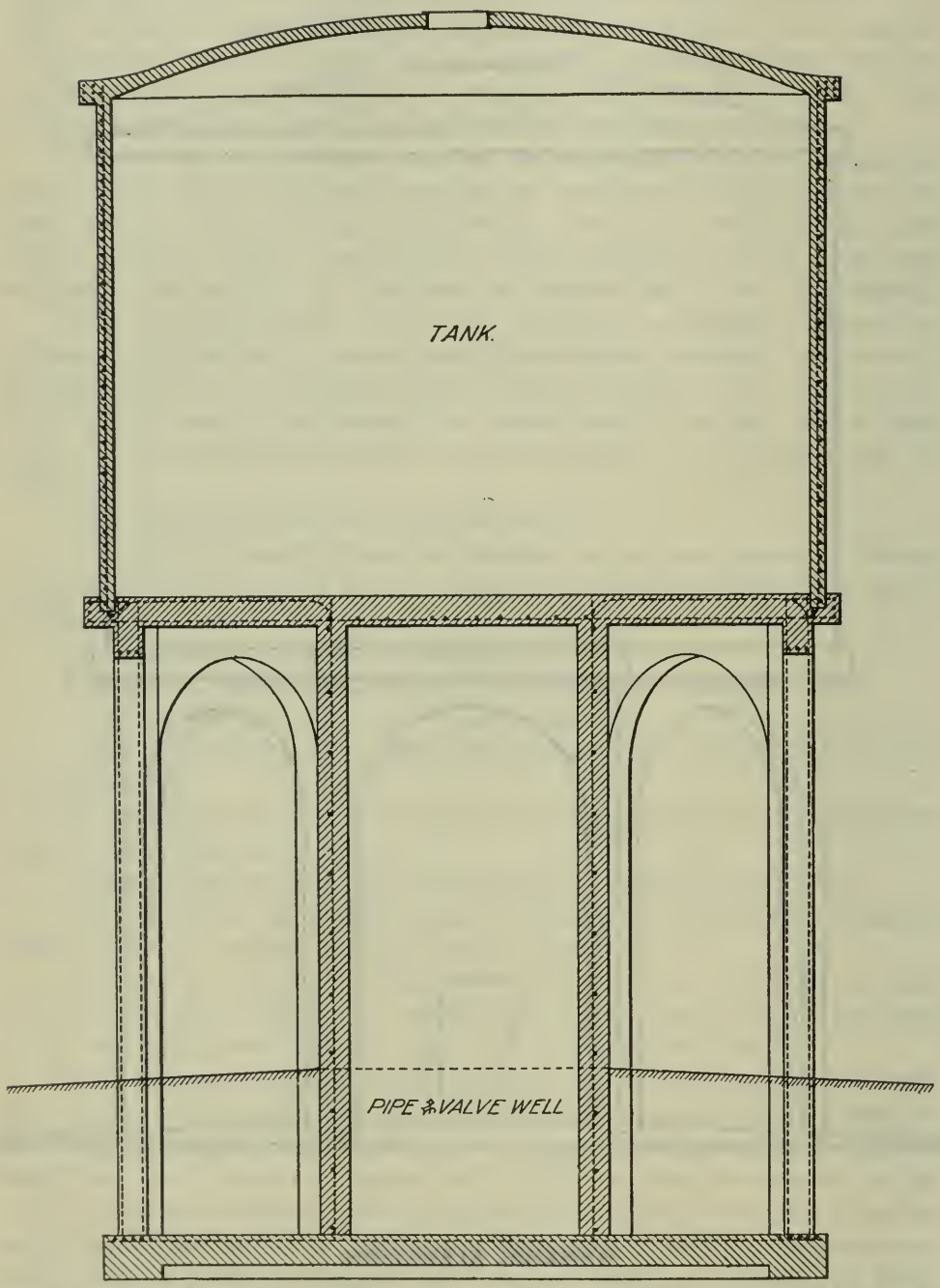
The construction of the concrete tank on the concrete substructure would not differ materially from that of the concrete standpipe, and the general specifications for the latter may be applied generally to the former.

The substructure may also be used for supporting tanks of wood or steel. Its general design consists of an octagonal foundation slab and an octagonal deck slab, the latter being carried on the reinforced columns



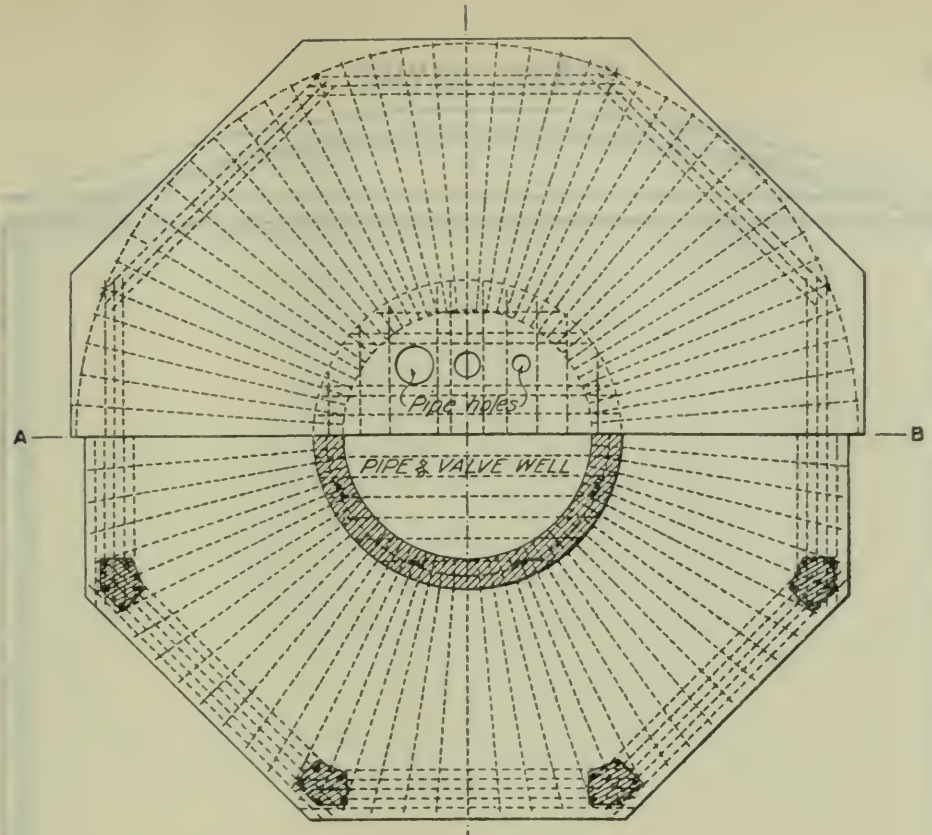
GENERAL ELEVATION.

FIG. 1—SUGGESTED GENERAL PLAN FOR A REINFORCED CONCRETE SUBSTRUCTURE AND A REINFORCED CONCRETE WATER TANK.
(Substructure may be used for Wood or Steel Tanks.)

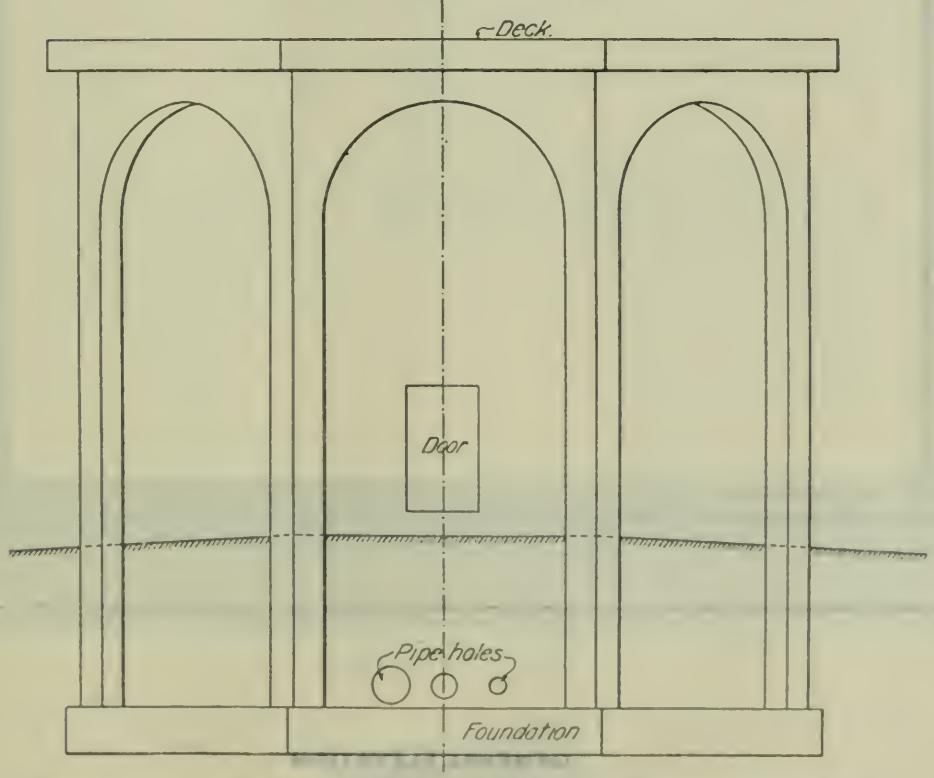


GENERAL SECTION ON A - B.

FIG. 2—SUGGESTED GENERAL PLAN FOR A REINFORCED CONCRETE SUBSTRUCTURE AND A REINFORCED CONCRETE WATER TANK.
(Substructure may be used for Wood or Steel Tanks.)



HALF DECK AND HALF FOUNDATION PLAN
OF SUBSTRUCTURE
SHOWING REINFORCEMENT



ELEVATION OF SUBSTRUCTURE.

FIG. 3—SUGGESTED GENERAL PLAN FOR A REINFORCED CONCRETE SUBSTRUCTURE AND A REINFORCED CONCRETE WATER TANK.
(Substructure may be used for Wood or Steel Tanks.)

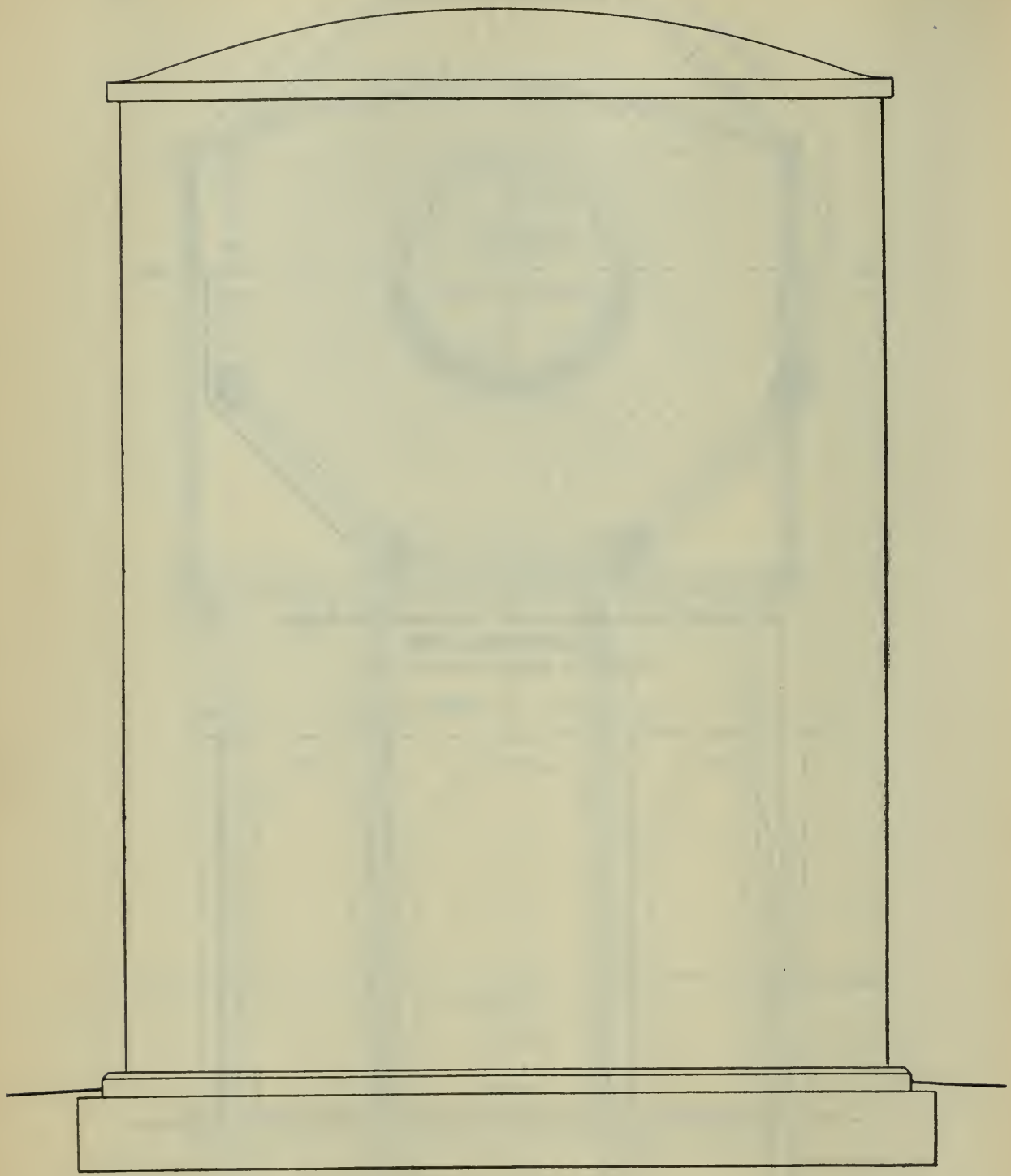
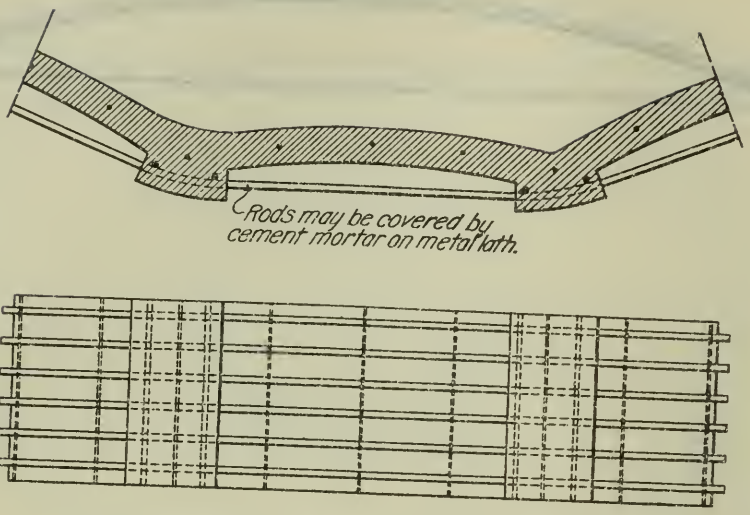
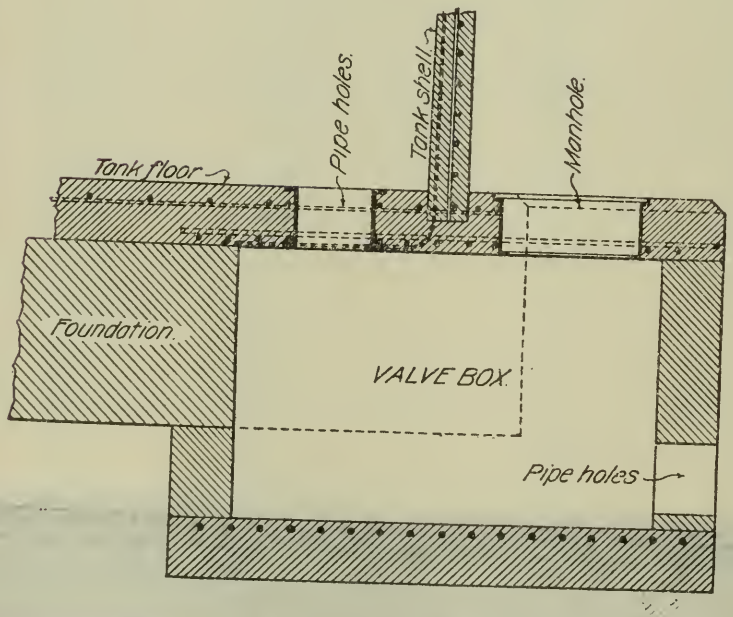


FIG. 4—SUGGESTED GENERAL DESIGN FOR A REINFORCED CONCRETE STANDPIPE.

FIG. 5—SUGGESTED GENERAL DESIGN FOR A REINFORCED CONCRETE STANDPIPE.



SUGGESTED PLAN AND ELEVATION FOR A CONCRETE TANK SHELL DESIGNED TO BE IN COMPRESSION



SUGGESTED SECTION THROUGH VALVE BOX

FIG. 6—SUGGESTED GENERAL DESIGN FOR A REINFORCED CONCRETE STANDPIPE.

and the central pipe and valve well resting on the foundation. The plan shows the general arrangement of the reinforcement. The foundation slab distributes the load under its entire area, keeps the unit load low and is favorable to uniform settlement, if any. On a rock foundation this slab may be omitted. The central well serves for enclosing and frost-proofing the piping and valves, helps to support the deck and makes the entire sub and superstructure stable against wind pressure without assistance from the surrounding columns. The plan contemplates a substructure not more than 20 ft. high above the ground, in which case the columns require no lateral bracing. In the construction of the substructure the ordinary approved building loads, stresses, materials and workmanship for reinforced concrete are acceptable and sufficient. The question of waterproofing does not enter unless it is desired to make the deck slab the bottom of the tank when the latter is made of concrete.

These general plans are submitted, not as those which should be adopted, but as suggestions for a number of good designs which could be made.

GENERAL SPECIFICATIONS FOR A REINFORCED CONCRETE STANDPIPE WATER TANK FOR RAILWAYS.

NO PLANS SUBMITTED.

Definitions.

1. The words "company," "engineer," "as shown," "drawings," and "this Association," appearing in these specifications are defined as follows:

"Company" means the railway company building a tank under these specifications.

"Engineer" means the engineer of the company.

"As shown" means as shown on the drawings.

"Drawings" means the drawings of the tank herein specified and forming a part of these specifications, including such working drawings as the engineer shall prepare or approve.

"This Association" means the American Railway Engineering Association.

Kind.

2. This tank shall be of reinforced concrete as shown

Excavations.

3. In earth, excavation for the foundation should be as deep as the lowest frost line. In rock, only the excavation for the valve box should be carried below the action of frost. In earth, the bottom of the excavations should be thoroughly tamped. If the earth will not sustain the total load, including wind pressure, without material or unequal settlement, the foundation should be supported on piles of the number, size and arrangement as determined by the engineer. Such piles should conform to the specifications of this Association for piling as selected by the engineer.

Foundation.

4. The foundation should be monolithic concrete of the form and dimensions as shown. If the depth of frost is excessive the foundation may be carried on broken rock uniformly compacted in the bottom of the excavation. The top of the foundation should be above the surface of the ground.

Floor.

5. The tank floor shall be constructed on the foundation as shown.

Valve Box.

6. The valve box shall be constructed as shown. When low temperatures require to prevent freezing within the valve box, an air space should be constructed in the middle of the valve box walls as shown.

Shell.

7. The concrete shell shall be constructed and the connection between it and the floor shall be as shown. Its thickness should have a proper relation to the sizes and positions of the reinforcing rods so that the concrete will not crack in shrinking around the rods.

Piping and Valves.

8. This tank should be equipped with standard iron pipes and standard gate valves located in the valve box as shown. The pipes should pass from the valve box in iron sleeves with lead joints into the tank as shown. There should be a tank supply pipe, a washout pipe, a water column supply pipe, and if required, an overflow pipe. For a gravity water supply, an altitude controlling valve in the valve box or a float valve in the tank should be placed in or on the tank supply pipe as shown. The tank supply pipe and the water column supply pipe should extend above the floor of the tank, but the water column supply pipe should not rise higher than the top of the water columns served. The washout pipe should terminate flush with the floor.

Gage.

9. The tank should be equipped with a gage, indicator and float as shown.

Ladder.

10. The tank should be provided with a ladder as shown.

Concrete.

11. The concrete in the floor, shell and roof shall be a thoroughly uniform and dense mixture of cement, sand, stone and water, made and laid in accordance with the specifications of this Association for reinforced concrete. The volume of the sand shall be in excess of the voids in the stone. The volume of the cement shall be in excess of the voids in the evenly mixed sand and stone. The excess of sand and cement shall be such as will give the greatest attainable density in the concrete. The volume of water shall be sufficient to give the concrete a fluidity that will cause it to flow and mold itself into the forms readily and completely. An unnecessary quantity of water shall not be used. The engineer shall determine the above specified voids and proportions.

In the foundation, the concrete shall be mixed in the proportions specified by the engineer and it shall fulfill the requirements of the specifications for concrete of this Association.

Mixing.

12. The concrete should preferably be mixed by batch mixing machines. The method used shall yield a complete and even mixture.

Cleanliness.

13. All dirt and foreign matter shall be excluded from all materials, concrete and stages of the work.

Pouring and Mixing.

14. This concrete, after mixing, shall be poured and worked into final position in the forms before its initial set is complete, and it shall not thereafter be disturbed. As it is thus placed, it shall be thoroughly worked throughout by flat thin bladed tools in a manner that will eliminate all voids and air pockets and produce unbroken mortar faces against all forms and secure perfect contact with every part of all reinforcing rods therein.

Joints.

15. The surface of concrete in joints should be free of laitance and all foreign matter and should be rough, fresh, clean and wet when concrete is laid thereon. The surface should be covered with a heavy coat of grout or mortar immediately in advance of placing concrete thereon. The surface should be thoroughly tooled, scrubbed and washed preparatory to the application of grout and concrete. The new concrete should be worked into complete contact with the old concrete.

Muriatic acid or equivalent may be used as a help to the tooling and scrubbing, but all of the concrete penetrated by the acid should be entirely removed.

A metal dam of non-corrosive metal like copper should be inserted in the concrete joints intended to prevent the passage of water. The metal should be driven edgewise into the first half of the joint to a depth equal to half the width of the metal before the initial set of the concrete is complete. The contact between the concrete and the metal should be complete and perfect. The edges of the metal should be turned over 90 degrees for anchorage. Joints in the metal dam should be lapped at the ends in a manner that will secure water-tight joints.

This specification for joints does not necessarily and preferably may not apply to the joint between the floor and the foundation.

The entire process of making joints shall be as required.

Wetting.

16. Rapid drying out of concrete shall be prevented by regular, frequent and continued wetting of all exposed concrete surfaces until all danger of arresting setting and hardening is past.

Freezing.

17. Freezing of concrete before it has finally set shall be prevented.

Broken.

18. Any concrete broken or displaced in any manner after having set shall be removed from the work.

Cement.

19. The cement shall conform to the specifications of this Association for Portland cement. It shall retain its original purity and qualities until it is incorporated into this work. Deteriorated or otherwise damaged cement shall not be used.

Sand.

20. The sand shall be clean, sound and sharp and it shall be of graded sized grains giving a minimum of voids.

Stone.

21. The stone shall be clean, sound and durable. The word "stone," includes broken rock and gravel. The stone shall be of graded sizes giving a minimum of voids. All of it shall be able to pass through a circular hole having a diameter of ¾-in.

Water.

22. The water shall be clean and free from anything injurious to the concrete.

Forms.

23. The concrete forms should be made of dressed and matched lumber or of metal. They should be accurately made and erected, be watertight, and should have ample strength and rigidity to prevent bending and warping under the load and action of the concrete. They should be erected in such manner as will permit the concrete to be poured and worked as above specified.

Pointing.

24. Any break in the concrete surfaces, not impairing the integrity of the structure, shall be pointed by cement mortar as the engineer shall direct. Any other imperfections in the concrete shall be treated and remedied as the engineer shall direct.

Reinforcement.

25. The concrete shall be reinforced by metal rods of the kind, form, size, number and arrangement as shown. They shall be maintained in required position as they are buried in the concrete, at which time they shall be free from dirt, paint, oil, grease and scale. Splices in a line of rods shall be lapped far enough to develop the full strength of each rod. Throughout the splice, the ends of the rods making it shall be far enough apart to develop maximum total adhesion of the concrete. Unnecessary splicing shall be avoided. No splice shall be opposite a splice in an adjacent line of rods.

Reinforcing Rods.

26. The rods shall be metal rods, plain or deformed. Their tensile strength shall be not less than 50,000 lbs. per sq. in. Their elastic limit shall be not less than 30,000 lbs. per sq. in. Their ductility shall be such

that any rod can be bent 180 degrees on a radius equal to 2 diameters or sides of the rod without sign of fracture.

Stresses.

27. Assuming the metal rods to carry the water pressure and other stresses without aid from the tensile strength of the concrete, the stress per sq. in. in the rods should not exceed 10,000 lbs. Vertical reinforcement in the shell, between the shell and the foundation and across joints in the concrete should be ample to prevent opening of cracks in the concrete. Reinforcement in all necessary directions should be ample to prevent as far as practicable the opening of cracks in the concrete due to its shrinkage in setting and to its stretching under the water load. The minimum thickness in inches of concrete at any point should be such that when the water load in pounds at that point is diminished by 3,000 times the sectional area in sq. in. of the metal reinforcement at that point, the remaining water load will stress the concrete not more than 300 lbs. per sq. in. at that point, provided that in no case shall the thickness be less than 4 in.

Loading.

28. The weight of water should be assumed to be 63 lbs. per cu. ft. Wind pressure, acting in any direction, should be assumed to be, in pounds, 30 times the product of the height by two-thirds of the diameter of the tank in feet.

Waterproofing.

29. A uniformly dense mixture of concrete as herein specified should be the primary expedient to secure water-tight concrete. This may be supplemented by mixing with the concrete some form of waterproofing compound of proved efficiency or by washing the concrete surface therewith, or by both.

The engineer shall select the waterproofing material and determine the proper proportions and methods of application.

Waterproofing by the application of rich cement mortar may be acceptable if the foregoing specification for making joints in concrete work is complied with.

*GENERAL SPECIFICATIONS FOR ORDINARY STEEL WATER AND OIL TANKS.

(Revised November, 1911.)

Ordinary Tanks Defined.

1. Ordinary tanks are those requiring plates not more than $\frac{5}{8}$-in. thick.

Scope of Specifications.

2. These specifications cover ordinary steel tanks commonly used by railways for usual service conditions only.

Quality of Metal.

3. The metal in these tanks shall be a special refined steel or open-hearth steel.

*For amendments, see Index.

The special refined steel shall have a tensile strength per sq. in. not less than 50,000 lbs. and an elastic limit not less than 30,000 lbs. per sq. in. It shall contain of

Sulphur	Not more than .02 per cent.
Phosphorus	Not more than .005 per cent.
Carbon	Not more than .02 per cent.
Manganese	Not more than .00 per cent.
Silicon	Not more than .00 per cent.

The open-hearth steel shall conform in physical and chemical properties to the specifications of this Association for steel bridges.

For plates not more than 3/8-in. thick, 5/8-in. rivets shall be used. For thicker plates the diameter shall be 3/4-in.

Loading.

4. The weight of water shall be assumed to be 63 lbs., crude oil 56 lbs., and creosote oil 66 lbs. per cu. ft. Wind pressure, acting in any direction, shall be assumed to be, in pounds, 30 times the product of the height by two-thirds of the diameter of the tank in feet.

Unit Stresses.

5. Unit stresses shall not exceed the following:

(a) Tension in plates, 15,000 lbs. per sq. in. on net section.
(b) Shear in plates, 12,000 lbs. per sq. in. on net section.
(c) Shear on rivets, 12,000 lbs. per sq. in. on net section.
(d) Bearing pressure on field rivets, 20,000 lbs. per sq. in.

Cylindrical Rings.

6. Plates forming the shell of the tank shall be cylindrical and of different diameters, in and out, from course to course.

Workmanship.

7. All workmanship shall be first class. All plates shall be beveled on all edges for caulking after being punched. The punching shall be from the surface to be in contact. The plates shall be formed cold to exact form after punching and beveling. All rivet holes shall be accurately spaced. Drift pins shall be used only for bringing the parts together. They shall not be driven with enough force to deform the metal about the holes. Power riveting and caulking should be used. A heavy yoke or pneumatic bucker shall be used for power driven rivets. Riveting shall draw the joints to full and tight bearing.

Caulking.

8. The tank shall be made water or oil tight by caulking only. No foreign substance shall be used in the joints. For water tanks, the caulking shall preferably be done on the inside of tank and joint only; but for oil tanks the caulking should be done on both sides. No form of caulking tool or work that injures the abutting plate shall be used.

Minimum Thickness of Plates.

9. The minimum thickness of plates in the cylindrical part of the tank shall not be less than 1/4-in. and in flat bottoms not less than 5/16-in.

In curved bottoms the thickness of plate shall be not less than that of the lower plate in the cylindrical part.

Horizontal and Radial Joints.

10. Lap joints shall generally be used for horizontal seams and splices and for radial seams in curved bottoms.

Vertical Joints.

11. For vertical seams and splices, lap joints shall be used with plates not more than 3/8-in. thick. With thicker plates, double butt joints with inside and outside straps shall generally be used. The edge of the plate in contact at the intersection of horizontal and vertical lap joints shall be drawn out to a uniform taper and thin edge.

Rivet Holes, Punching and Pitch.

12. The diameter of rivet holes shall be 1/16-in. larger than the diameter of the rivets used. The punching shall conform to the specifications of this Association for such work on steel bridges. A close pitch, with due regard for thickness of plate and balanced stress between tension on plates and shear on rivets, is desirable for caulking.

Tank Support.

13. If the tank is supported on steel columns with bracing, the metal in such substructure shall conform to these specifications, and the anchorage and workmanship thereof shall conform to the specifications of this Association for the manufacture and erection of steel bridges.

Painting.

14. In the shop the metal shall be cleaned of dirt, rust and scale and, except the surfaces to be in contact in the joints of the tank, shall be given a shop coat of paint or metal preservative selected and applied as specified by the company.

After being completely erected, caulked and cleaned of dirt, rust and scale, all exposed metal work shall be painted or treated with such coat or coats of paint or metal preservative as shall be selected by the railway company.

Plans and Specifications.

15. Under these specifications and in conformity thereto the railway company shall cause to be prepared or shall approve detailed plans and specifications for such tanks, herein specified, as it shall construct. Such plans and specifications shall cover all necessary tank auxiliaries.

CONCLUSION.

That the specifications for steel, water and oil tanks is good practice, and should be included in the Manual.

Respectfully submitted,

COMMITTEE ON WATER SERVICE.

Appendix A.

LOCOMOTIVE BOILER CORROSION AND TREATED WATER.

NOTE BY THE COMMITTEE.

The installation of small pumps to discharge a definite quantity of soda ash, in solution, into water tanks instead of relying upon enginemen to place the soda ash itself in the engine tender is not new, as a number of such outfits are in service for the purpose of relieving conditions where the hardness of water from sulphates occurs at points which are not equipped with softeners or where the conditions would not justify that expense, but your Committee believe such installation for the purpose of preventing pitted flues, as described in this article, is new and it is therefore brought to your attention.

Your Committee wish to point out for the benefit of members who may not have had enough chemistry to fully comprehend the suggestions which would otherwise occur, that the pitting of flues was stopped by maintaining in the boiler at all times water slightly caustic from sodium hydrate, and that control of this causticity was made by continuous chemical examination of samples of water taken from the boilers at the terminal or at points between terminals as may at times seem desirable, this examination being for the double purpose of maintaining no greater causticity than necessary and to furnish data for use in cases of alleged foaming trouble and failure to use blow-off cocks. It is the practice on some roads to secure more effective removal of sludge through blow-off cocks by connecting them to a perforated pipe which is laid on the mud-ring and thus withdraw the sludge from the entire ring instead of only in the vicinity of the cock.

The control of boiler waters required to make these caustic soda stations successful can best be made by a Chemist and Engineer of Tests, but railroads, suffering from thin traffic as well as bad water and unable to afford the expense of a man to devote his exclusive services to such matters, may be able to find a local chemist familiar with water analysis who would be equipped to do such work.

LOCOMOTIVE BOILER CORROSION AND TREATED WATER.

By J. R. Francis, Indianapolis, Ind.

During the Fall of 1908, the writer at the time being in charge of the chemical work for the company, locomotive boiler corrosion of a serious nature developed on the Peoria & Eastern Division of the Big Four Railway.

The Division referred to as relates to engine service being divided at Indianapolis, Indiana, "West End" engines working between Indianapolis and Peoria (Illinois), and "East End" engines between Indianapolis and Springfield (Ohio), excepting during unusually busy periods, when engines were occasionally transferred for several runs from one district to the other, engines from both districts, however, running into Moorefield round-

house at Indianapolis and taking water before leaving Indianapolis on their runs from Moorefield water softener, the latter being a standard, Davidson type, continuous system machine, using lime and soda ash in the usual manner. The water softener referred to had been in continuous service ten months prior to the first evidence of corrosion troubles, and had served as the exclusive water supply for the yard engines working in Moorefield yards, the stationary boilers at Moorefield shops and roundhouse, and the road engines, as before stated.

The first evidence of corrosion in boilers of road engines was reported under date of October 8, 1908, in the case of freight engine 6169 on the "East End" giving up train on account of bursted flue, which upon examination together with entire set of flues, revealed a bad case of pitting and corrosion. Following this experience in rapid succession and extending over a period of several months, engine failures due to pitted flues were frequent, a total of 3,335 flues being scrapped in 1909, and 1,069 in 1910. At about the time of the first case in question, the General Foreman of Moorefield shops and roundhouse reported that an occasional nipple or elbow in the feed pipes of the stationary boiler plant, between the feed water heater and boilers, had to be removed on account of being honeycombed by pitting, and that this trouble had developed after the installation of the water softener, the pipes previous to the installation of the latter becoming limed up badly from time to time. Within a short time after this report, yard engine 6522, which had been in service at Moorefield yards and using treated water from Moorefield water softener exclusively, was taken to the Division shops at Urbana, Illinois, where upon being overhauled it was found that the entire set of flues were pitted so badly that they had to be scrapped. In the light of the above-mentioned cases, namely, road engines failing on account of pitted flues, nipple and elbows in feed water line of stationary boiler plant pitting, and a yard engine turning up with entire set of flues useless on account of pitting, and in each case the treated (softened) water having been used exclusively or in part, it is not surprising that suspicion pointed, as it did on the part of the Division officials, toward the water softener; in fact, it was the only new or unusual thing to be found in connection with the water service.

Upon investigation, by a process of elimination as it were, it was found that the stationary boilers of the Moorefield plant were in excellent condition, with no evidence whatever of any pitting or corrosion; that the yard engine in question had been in service at another point where a hard water had been used before coming to Moorefield yards, and that the road engines affected were confined to those which were in service exclusively or most of the time on the "East End." Samples of boiler waters from all engines coming into Moorefield roundhouse were then called for, with the object of noting by chemical examination what difference, if any, existed in the condition of concentrated waters of "East End" boilers as compared to "West End" boilers. These samples were drawn at the water gage in a bucket, allowed to cool, bottled, tagged as to

number of engine, East End or West End, dated, and forwarded to the laboratory for examination. At the laboratory the examination was conducted as follows:

One hundred c. c. of sample was titrated with phenolpthalein indicator and normal ten hydrochloric acid, the number of c. c. of acid required being noted and the titration completed with methyl orange indicator, the number of c. c. of additional acid required with this indicator noted, and also the total number of c. c. of acid required with both indicators. For the purpose of explanation, we will call this operation the "First Step." Another 100 c. c. of sample was then taken and 30 c. c. of a 10 per cent. solution of barium chloride added, with phenolpthalein indicator, and the mixture titrated with normal ten hydrochloric acid, the number of c. c. of acid required being noted and set down as the "phenolpthalein titration of the second step."

In arriving at results from the above, the following procedure was observed: If the acid required with phenolpthalein indicator in the first step exceeded that required by methyl orange, the difference was charged to hydrates and reported in equivalents as sodium hydrate. The amount of acid required with phenolpthalein indicator in the second step was compared with the amount required with phenolpthalein indicator in the first step. If less, the difference was multiplied by two and charged to alkaline carbonates and reported in equivalents as sodium carbonate. The total acid required by sodium hydrate and sodium carbonate was then deducted from the total acid required by both phenolpthalein and methyl orange indicators (the total alkalinity), and the difference, if any, charged to alkaline earth carbonates and reported in equivalents as calcium carbonate.

In case the acid required with methyl orange in the first step was greater than that required with phenolpthalein, the difference was charged to bi-carbonates and reported in equivalents as sodium bi-carbonate. The second step was then conducted same as before, the sum of the sodium bi-carbonate and carbonate substracted from the total alkalinity, and the difference charged to alkaline earth carbonates and as before, reported as calcium carbonate.

The use of hydrochloric acid instead of sulphuric acid in the titration is obvious, on account of the use of barium chloride.

By way of comment on the above procedure, no claim is made for scientific accuracy, because the steps as outlined are not absolutely accurate. They are, however, sufficiently so to serve the purpose to which they were put, and reference for explanation in detail will be found in "Sutton's Volumetric Analysis," under "Titration of Alkaline Salts." Besides the above figures on the samples, we also titrated for the chlorine content with standard silver nitrate solution in the usual manner, save that we first carefully neutralized the sample with nitric acid.

The following is a transcript of results of laboratory examinations as per above, of a few boiler water samples:

BOILER WATERS EAST END PASSENGER ENGINES

(Corrosion occurring)
(Note absence of Sodium Hydrate in appreciable quantity, and presence of Sodium Carbonate and Bi-Carbonate)

Parts per 100,000

Date	Engine Number	Sodium Carbonate	Sodium Bi-Carbonate	Sodium Hydrate	Calcium Carbonate	Chlorine
October 30, 1908.....	7077	2.12	....	0.80	6.00	27.00
October 30, 1908.....	7113	2.12	0.84	....	8.00	30.80
October 30, 1908.....	7071	2.12	....	.40	8.00	43.00
November 2, 1908	7071	4.24	4.20	....	2.00	35.80

BOILER WATERS EAST END FREIGHT ENGINES

(Corrosion occurring)
(Note absence of Sodium Hydrate and presence of Sodium Carbonate and Sodium Bi-Carbonate)

Parts per 100,000

Date	Engine Number	Sodium Carbonate	Sodium Bi-Carbonate	Sodium Hydrate	Calcium Carbonate	Chlorine
October 31, 1908.....	6595	2.12	3.36	....	1.00	24.20
November 2, 1908	6577	2.12	2.52	....	5.00	16.60
November 24, 1908 ...	6571	4.24	1.68	....	5.00	35.20
November 24, 1908 ...	6586	5.30	2.52	....	3.00	28.00
November 24, 1908 ...	6597	4.24	2.52	....	2.00	29.80

TECHNICAL ANALYSES, WATER SUPPLIES, EAST END

Station No. 1. Moorefield treated water. Total hardness averaging less than 5 grains per gallon to standard soap solution. Total causticity averaging about 3 grains per gallon. Sodium chloride average, 3.13 grains per gallon.

WATER STATIONS.	No. 2. Fairbanks, Ind.	No. 3. Maxwell, Ind.	No. 4. New Castle, Ind.	No. 5. Lynn Ind.	No. 6. Arcanum, Ohio.	No. 7. Troy, Ohio.	No. 8. Durbin, Ohio.
	Grains, U. S. Gallon						
Total Solids	25.62	21.93	23.94	22.68	38.73	22.77	29.01
Volatile	2.34	1.16	0.20	3.52	3.68	2.05	2.15
Fixed Solids	23.28	20.77	23.74	19.16	35.08	20.72	26.86
Incrusting Solids	22.08	19.39	22.14	18.38	32.93	20.07	25.26
Non-Incrusting Solids	1.20	1.38	1.60	0.78	2.12	.65	1.60
Composition of Incrusting Solids Hypothetical Combinations:							
Silica	.54	1.08	1.35	.60	.99	.69	.81
Iron Oxide and Alumina	.12	.51	.24	.12	.15	.12	.12
Calcium Carbonate	13.50	11.74	13.43	11.03	19.00	10.80	14.93
Calcium Sulphate	2.37	.....	.....	.....	.....	.....	.....
Magnesium Carbonate	.....	6.06	7.12	3.36	2.95	4.26	4.63
Magnesium Sulphate	5.55	.....	.....	3.27	9.47	3.91	4.77
Magnesium Chloride	.....	.....	.....	.....	.37	.29	.....
Composition of Non-Incrusting Solids, Hypothetical Combinations:							
Sodium Chloride	1.20	.98	.99	.78	2.12	.65	1.60
Sodium Sulphate	.....	.40	.61	.....	.....	.....	.....
Total Sulphuric Anhydride	5.15	.29	.31	2.25	6.31	2.61	3.19

Station No. 9. Springfield, Ohio, treated water, averaging same as Sample No. 1. Machine Standard American Continuous System. Sodium Chloride average, 1.00 grain per gallon.

BOILER WATERS WEST END PASSENGER ENGINES
(No corrosion occurring)
Parts per 100,000

Date	Engine Number	Sodium Carbonate	Sodium Bi-Carbonate	Sodium Hydrate	Calcium Carbonate	Chlorine
October 28, 1908.....	7072	19.08	....	14.00	2.00	16.40
October 28, 1908.....	6159	21.20	....	18.80	3.00	24.00
October 29, 1908.....	7080	19.08	....	14.60	0.00	18.20
October 30, 1908.....	7115	15.60	....	7.60	6.00	16.40

BOILER WATERS WEST END FREIGHT ENGINES
(No corrosion occurring)
Parts per 100,000

Date	Engine Number	Sodium Carbonate	Sodium Bi-Carbonate	Sodium Hydrate	Calcium Carbonate	Chlorine
October 28, 1908.....	6591	3.18	....	1.20	9.00	30.20
October 29, 1908.....	6584	4.24	....	1.60	5.00	19.80
November 24, 1908...	6589	5.30	....	4.00	2.00	26.00

It will be noted that the average chlorine content of all waters on the East End is about 1.39 parts per 100,000, and that they do not vary a great deal. Comparing this average figure with chlorine content of East End freight engine No. 6571 boiler water, reported above as having a chlorine content of 35.2 parts per 100,000, we note a concentration of about 25 times.

Attention is called to this observation for the reason that where the chlorine content of water supplies within a district are approximately the same, by comparing the average figure with that found in concentrated boiler water samples, a figure is obtained which serves as an index to the concentration of the boiler water and may be used to check up engine crews working under instructions as to blowing down of boilers, and to check up round house practice as to washing boilers, changing water, etc.

Concerning the general character of the water supplies of the East End as reported in the analyses above, as relates to the corrosion experienced, it will be noted that none of them are "acid waters." On the contrary, they are so-called alkaline waters, and two are treated waters, showing, as a result of treatment, a slight causticity. Ordinarily one would not expect to find corrosion following the use of such waters, and with corrosion occurring, as it did, with their use, it is quite a temptation to theorize as to the exact cause of the corrosion. By way of comment it may be stated that upon chemical examination of corroded or pitted spots of sections of affected flues, taken while yet moist and before samples had had time to become oxidized, the content of such pitted vesicles contained, according to qualitative analysis, ferrous iron and sulphuric anhydride, while on surfaces of other portions of the sections, alkaline earth carbonates were in evidence, most of the pitted and corroded spots on the cleaner flues being universally on the under or lower side.

In searching for a cause for the corrosion, no attention was paid to the composition of the flues in use, further than to establish the fact

that the flues in service on this Division were no different from flues furnished other Divisions of the company where no trouble was being experienced in the use of mixed, treated and untreated, waters.

Attention should be called to the fact, however, that many of the flues affected (not all of them) had been in use some time prior to the installation of water softeners at each end of the district, and as a consequence were heavily covered with hard scale, the worst corrosion when appearing in the form of blisters in contradistinction to pitted points, occurring in its most active form immediately under the edge of adherent scale. An analysis of a sample of scale, showing:

	Per cent.
Silica	1.48
Ferric oxide	17.47
Calcium carbonate	9.32
Calcium sulphate	65.92
Magnesium oxide	5.62
Ferrous iron	Trace
	99.81

Considering the ferrous iron and sulphuric anhydride found by qualitative analysis of contents of pitted vesicles as mentioned, one might theorize that the sulphates of the alkaline earths had been broken down under the influence of carbon of organic matter, high heat, pressure, etc., but in the examination of the water supplies, no organic matter in appreciable quantity was found. Passing by the exact cause of the corrosion, since, under the conditions under which it took place, any explanation would of necessity be hypothetical in its details, the remedy for counteracting and stopping the trouble was based on the information obtained in the chemical examination of the boiler waters of West End engines as compared to those of the East End. The West End boilers giving no trouble and being quite caustic in comparison, it was concluded that if East End boilers had caustic in some form added by the injection of same into the raw water supplies, thereby keeping the East End boilers slightly caustic due to "hydrates," that the trouble, pending the installation of additional standard water softeners, would cease.

This recommendation accordingly went out from the laboratory in December, 1908, and again in January, 1909, but on account of diversity of opinion as to the cause of the corrosion, some of the official staff believing that Moorefield treated water was causing the trouble, the use of the caustic was not begun until March 5, 1909. On this date the use of caustic soda at Arcanum (Ohio) water station was commenced. Nine grains per gallon, in form of solution being injected into delivery line from the large pump discharging into the wayside tank. The apparatus used consisted of a "Gould's Plunger Boiler Feed Pump No. 2," Fig. 485, Fairbanks, Morse & Co.'s catalogue 1909, price about $10, and having a plunger one and a quarter inches in diameter which was attached to the large pump in such manner that it had a stroke of three inches with each stroke of the large pump. This small pump was connected to iron

tank having a capacity of about 200 gallons, in which the caustic soda solution was diluted to the desired strength, and discharged into the discharge line of the large pump. It is advantageous to have the line from small pump enter the discharge line of the large pump as near the tank as possible, on account of the gradual deposit in the pipe occasioned by the interaction of the caustic soda with chemical salts in solution in the raw water.

On May 1, 1909, a similar outfit was put in operation at Troy (Ohio) water station, and four grains per gallon of caustic soda used there. Following these installations at stations named, a passenger engine which had been overhauled at shops and given an entire new set of flues, was caused to double the district until 28,000 miles had been made, when several flues were removed for examination. These were found to be without any evidence of pitting or corrosion.

During the treatment of these waters as mentioned above, namely, nine grains per gallon of caustic soda at Arcanum and four grains per gallon of same at Troy, Ohio, boiler water samples titrated as follows:

BOILER WATERS EAST END PASSENGER ENGINES
(No corrosion occurring at this time)

Date	Engine Number	Sodium Carbonate	Sodium Bi-Carbonate	Sodium Hydrate	Calcium Carbonate	Chlorine
August 12, 1909.....	7071	3.8	....	4.40	1.00	16.0
September 3, 1909....	7081	2.12	....	2.80	....	13.0

It is proper to explain that passenger engines on the East End on their runs east, took water at Moorefield water softener, New Castle (Ind.), Arcanum (Ohio), and, going west, at Springfield (Ohio) water softener, Troy (Ohio) and Lynn (Ind.). This being true, they received a larger amount of caustic soda in proportion to the total amount of water used than did freight engines which used water from all water stations.

BOILER WATERS EAST END FREIGHT ENGINES
During treatment of waters at Arcanum (Ohio), and Troy (Ohio), as mentioned
Parts per 100,000
Total of 59 samples

Date	Engine Number	Sodium Carbonate	Sodium Bi-Carbonate	Sodium Hydrate	Calcium Carbonate	Chlorine
July, 1909.....	Total	40 Samples From 0.85 to 7.42		5 Samples None 35 Samples 0.16 to 8.40	....	40 Samples 3.00 to 25.40
		Av. of 5.43		Av. 2.81		Av. 14.24
		19 Samples From 2.12 to 9.54	19 Samples From 0.84 to 6.72			19 Samples From 12.00 to 17.20
		Av. of 5.43	Av. of 2.92			Av. of 14.92

It will be noted in the above that out of 59 samples, 35 or about 59 per cent. of them showed presence of sodium carbonate and sodium hy-

drate. Five of them, or approximately 8 per cent., showed sodium carbonate, but no sodium hydrate. And that nineteen samples, or about 33 per cent., showed sodium carbonate and sodium bi-carbonate.

It was believed at this time, on account of fewer engine failures account of flues, that under this treatment the corrosion was under control. This assumption, however, was likely not true, as it afterwards was demonstrated that the corrosion did not entirely stop until a causticity due to "hydrates" was maintained practically all of the time.

The treatment of the waters at Arcanum and Troy, in the proportions already stated, was continued until November 1, 1909, when it was reduced one-half on account of complaint on the part of enginemen that the treatment of the water was causing foaming.

It developed later, however, that the greater part of these complaints was occasioned by an effort on the part of the enginemen to protect one of their number who had carelessly allowed the water to run low in a boiler and burned a crown-sheet. This reduction in treatment lowered the percentage of boiler water samples, showing the presence of sodium hydrate so much, that the majority of the samples showed the presence of sodium bi-carbonate instead.

Within four months after the reduction in the treatment several engine failures on account of pitted flues again occurred, and on this account the treatment of the waters at Arcanum and Troy was increased on June 10, 1910, to the figures as at first used, following which a systematic patrol of the district by the Road Foreman of Engines quieted the complaints on the part of enginemen concerning foaming, it being very clearly demonstrated that these complaints had been greatly exaggerated. Sampling and examination in the laboratory of boiler waters was continued as before, the object being to raise the causticity due to sodium hydrate until all boiler samples showed the presence of at least a slight amount.

This feature was not finally accomplished until a third caustic soda treating station was established at Maxwell, (Ind.) water station, August 12, 1910, where two grains per gallon was injected into the raw water supply. With this additional installation in operation, no more trouble was experienced as to samples of boiler waters failing to show the presence of sodium hydrate in appreciable quantities. This point for the third installation was selected on account only of its distance from the other installations. The daily sampling of locomotive boiler waters and chemical examination, as described, was continued for seven months, during which time more than 90 per cent. of all samples showed the presence of two to 15 parts per 100,000 of sodium hydrate along with about an equal amount of sodium carbonate.

Under this treatment the corrosion entirely ceased and no more trouble on this account was experienced, neither was there any more complaint of moment on the part of engine crews on account of foaming boilers, the enginemen apparently having learned better how to handle the boilers under the treatment.

It is also worthy of note that under this treatment the boilers became and remained clean and practically free from scale.

To recapitulate, it is desired to call attention to the fact that between November 1, 1909, and June 10, 1910, when the treatment was reduced, with corrosion re-occurring as already stated, that the freight engine boiler waters did not show the presence of sodium hydrate in appreciable amounts with any regularity. They did, however, show the presence of small quantities of sodium carbonate and bi-carbonate. It is desired to emphasize this point because of the fact that only after a sufficient quantity of caustic soda had been added to show an appreciable amount in the concentrated boiler waters, did we succeed in stopping the corrosion.

It is also worthy of note that, in the use of the caustic soda, we at no time used an amount so large as the equivalent of the half-bound carbonic acid of the alkaline earth bi-carbonates in the waters naturally, therefore it must have followed that the caustic soda so used, when injected into the raw waters, became sodium carbonate and that it was finally hydrolized within the boiler and partially re-converted into "hydrate." The question naturally arises at this point why sodium carbonate (soda ash) would not have done just as well as sodium hydrate, since it is obvious that the latter when added to the raw water first became sodium carbonate and afterwards was in part re-converted by hydrolysis into "hydrate." In our opinion this probably would have been the case, since it is clear that sodium carbonate and sodium bi-carbonate are partially hydrolized within a boiler. This point is again clearly brought out by reference above to the titration of West End boiler water samples from passenger engines. These samples showing from seven to eighteen parts per 100,000 of sodium hydrate along with a slightly larger amount of sodium carbonate, and being accounted for only by the fact that, in addition to the treated water taken at Moorefield shops, two raw waters on the West End carry sodium bi-carbonate naturally, one of them about four parts per 100,000 and the other eight parts per 100,000, the presence of the sodium hydrate occurring on account of the partial hydrolysis of same within the boiler during concentration.

In our opinion, the features worthy of note concerning the above experience consists in part of the troubles which may follow the installation of standard water softening or treating apparatus, where waters in part only are treated within a district.

Also, in the importance of chemical laboratory examination and control of boiler waters, where corrosion as described is being experienced, the features of such control aiming to maintain within the boilers a causticity due to the presence of "hydrates" in an appreciable amount, and that whether sodium hydrate or soda ash be used, that it be used in sufficient quantity and so distributed that boiler water samples upon chemical examination show an appreciable amount of causticity due to "hydrates." This plan, in our opinion, insuring a sufficient treatment to counteract the "permanent hardness" of all waters used, therefore controlling ordinary corrosion troubles, and doing so without using an undue excess of reagent, thereby guarding against any unnecessary aggravation of foaming troubles, due specifically to excessive treatment.

REPORT OF COMMITTEE XIX—ON CONSERVATION OF NATURAL RESOURCES.

E. O. Faulkner, *Chairman;*
R. H. Aishton.
Moses Burpee.
F. F. Busteed.
C. H. Fisk.
William McNab, *Vice-Chairman;*
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G. A. Mountain.
W. L. Park.
G. H. Webb.

Committee.

To the Members of the American Railway Engineering Association:

The Board of Direction assigned the following subjects to your Committee:

(1) Continue the study of tree-planting and general reforestation.

(2) Continue the study of coal and fuel oil resources.

(3) Continue the study of iron and steel resources.

The Committee held a number of meetings during the year, and its researches have been along the general lines suggested by the Board of Direction.

In presenting the report, which is naturally one of progress, the Committee realizes that there is a great difference between the practical application of "Conservation of Natural Resources" to the every-day business conditions met with by the members of the Association and the purely sentimental ideals which may be indulged in by the world in general.

It is felt also that while the Committee was originally formed to cooperate with the National Conservation Commission of this country, as well as with the Commission of Conservation of Canada, yet its principal object was to keep under special observation those particular features in which the railways were directly and practically interested.

It is hoped that the information which the Committee has been able thus far to collect, may, in the method and form in which it is here given, be easy of reference as well as productive of practical benefit to our members, and through them to the railways in general.

Respectfully submitted,

COMMITTEE ON CONSERVATION OF NATURAL RESOURCES.

UNITED STATES.

TREE PLANTING AND GENERAL REFORESTATION.

As leading up to the necessity for tree planting and reforestation, it would seem desirable to consider, first, the extent and location of existing forests, their annual increment, and the yearly consumption of forest products.

These questions were very fully reported upon by the National Conservation Commission. The Commission was assisted in its labors by experts whose papers form the basis of the report. These papers, representing as they do the original work of experts, form a body of evidence along the various lines pertaining to the timber resources of the country, which will be found valuable for reference.

For the purpose of facilitating a thorough examination of any of the subjects treated in the following report, references are given to these papers as well as to other sources of information, easily obtainable, and which present the matter in sufficient detail to enable a careful study of the various problems to be made.

It was the feeling of the Committee that owing to the magnitude of the questions involved the best results would be obtained by a general review of the subject supplemented by a list of references to authoritative literature. The list of references, while small, is believed to cover the ground sufficiently for the purpose.*

The original forests of the United States (note A) exceeded in the quantity and variety of their timber the forests of any other region of similar size on the globe. Five great forest types were distinguished—the northern, southern, central, Rocky Mountain and Pacific Coast. The kinds of timber and extent of these forests are presented in Table 1.

TABLE 1.

ORIGINAL FORESTS OF THE UNITED STATES.

Forest.	Kinds of Timber.	Quantity Billion F. B. M.	Extent Million Acres.
Northern.....	Cone-bearing trees predominating with some hardwoods.	1,000	150
Southern.....	Coniferous forest with yellow pine predominating. Interspersed with the pine were a variety of hardwoods.....	1,000	220
Central.....	This is the only forest region in the United States in which the hardwoods predominated.	1,400	280
Rocky Mountain.....	Almost entirely coniferous.....	400	110
Pacific.....	Almost entirely coniferous.....	1,400	90
Total.....	.....	5,200	850

*A very complete Bibliography bearing upon the subject-matter of this report is to be found in Fernow's excellent book, "Economics of Forestry," B. E. Fernow, New York, pp. 491-507.

In addition to these timbered areas there were probably 100,000,000 acres of scrubly forest and brush land, chiefly in the West, which has been and still is a source of much post and fuel material.

The Bureau of Corporations (note B) estimates that there is a total of about 2,800 billion board feet of standing timber in the country. Of this about 2,200 billion feet is privately owned, about 539 billion feet is in the National forests, and about 90 billion feet is on the unreserved public lands, national parks, state lands, and Indian reservations.

The results of the Bureau's investigation of the amount of standing timber in the United States may be summarized as shown in Table 2.

TABLE 2.

STANDING TIMBER IN THE UNITED STATES.

		Billion Feet.
Privately owned timber in investigation area:		
Pacific Northwest	1,013	
Southern Pine Region	634	
Lake States	100	
	1,747	
Outside of investigation area	450	
		2,197
Total owned by Federal Government in National forests		539
Total otherwise owned by Federal Government, owned by states and on Indian reservations		90
Grand Total		2,826

The earliest attack was upon the white pine of the Northeast, the original stand of which is almost entirely cut out. From Table 2 it is apparent that at the present time the two great sources of timber supply, so far as privately owned timber is concerned, are the Pacific Northwest, with 1,013 billion ft. and the Southern pine region, with 634 billion ft. Moreover, 82 per cent. of the standing timber owned by the United States Government is in the Pacific Northwest, and nearly all of the remainder is in the other states of the Rocky Mountain region.

The yearly growth of wood (note C) in our forests does not average more than 12 cu. ft. per acre. This gives a total yearly growth of less than seven billion cubic feet.

That our forests grow very slowly, although the individual trees of many kinds grow fast, is our fault. There are about 200 million acres of mature forest mainly in the northern Rockies and on the Pacific Coast in which the yearly growth is balanced by decay.

There are 250 million acres, mostly in the Southern mountains and Southern pine belt, partly cut or burned over, but restocking naturally with young growth and 100 million acres chiefly in the Lake States and Southern pine belt which have been cut or burned over upon which young growth is wholly lacking or too scanty to make merchantable timber.

There is taken from the forest (note D) annually, not including loss from fire, 23 billion cubic feet of wood or over three times its yearly growth. This large consumption amounts to 230 cubic feet per capita, while Germany uses 37 cubic feet and France 25 cubic feet.

Each year there is used 90,000,000 cords of fire wood, 40,000,000,000 board feet of lumber, more than 1,000,000,000 posts, poles and fence rails,

118,000,000 hewn ties, 1,500,000,000 staves, over 133,000,000 sets of heading, nearly 500,000,000 barrel hoops, 3,000,000 cords of native pulp wood, 165,000,000 cubic feet of round mine timbers, and 1,250,000 cords of wood for distillation.

The condition of the world supply of timber makes us already dependent upon what we produce. There is exported out of the country one and one-half times as much timber as is brought in, and except for finishing woods, relatively insignificant in quantity, we must rely upon our own resources for the future supply.

The Forest Service estimates the yearly drain on the saw timber of the country at about 50 billion board ft. Without allowing either for new growth or for any increase in the rate of consumption the total for all the timber in the United States (see Table 2) would represent about 55 years' supply, and that for privately owned timber alone only 44 years' supply.

These conditions affect the railroads of the country not only as they are concerned in the production of timber for their own use, but from the broader viewpoint of developing the territory traversed by their lines. The destruction of the timber is followed by a rapid decline of the industries utilizing the products of the forest with a corresponding loss of revenue for the roads serving the region.

Turning our attention to the conservation of the forest it will be seen, (1) that by the introduction of proper forestry methods the annual productivity of the forest can be considerably increased (note E) and, (2) that the yearly loss from avoidable causes is much greater than it should be (note F).

There are 225 million acres of producing forest in the country. On this area the stand is so open that all the trees could be grown on 145 million acres, which would be producing at the rate of 70 cu. ft. per acre annually. By growing only the best species this growth can be increased to 80 cu. ft., an increase of 1,450 million cu. ft.

There is an unutilized area of 80 million acres within our present producing forest. There are 135 million acres of absolute forest land within our virgin or mature forests now unproductive. There are 90 million acres of waste lands which can be made productive by planting, or by fire protection all of these areas can be made to produce 80 cubic feet per acre, or a total of 24,400 million cu. ft.

The total increase possible in the productiveness of our forests is, therefore, 25,850 million cu. ft.

Only 25 per cent. of the yield of our present producing forest is saw timber. It can be made from 50 per cent. to 75 per cent. saw timber through the concentration of growth on the best trees by thinning and the holding of the crop until it reaches good size. This would mean an increase, if all our forest land were productive, from 27,000 million board ft. to between 54,000 million and 81,000 million board ft. per annum.

The enormous loss from fire in our forests every year is a matter of

common knowledge. The value of standing timber destroyed each season from this cause has varied from $25,000,000 to more than $100,000,000, the direct annual loss in recent years averaging considerable over $50,000,000. The destruction of young growth, though never included in estimates of fire damage, is a principal item of loss. The natural restocking of burned-over lands takes place very slowly or not at all

All experiences go to prove that damage by forest fires is practically preventable. This stage of development has already been reached in Europe. For example, of 7 million acres in Prussia, an average of only 1,400 acres or one-fiftieth of 1 per cent. was burned over each year during the period from 1868 to 1895.

Your Committee feels that the railroads by working with the State Forestry officials can accomplish a great deal of good in the way of prevention of fires started by sparks from locomotives. The Committee is assembling information from both the railroad companies and the State Forest officials in regard to the laws governing the subject and the means used in different parts of the country to reduce the fire risk from this cause.

It would appear that a concerted action on the part of the railroads and State officials is desirable as the forest adjacent to the railroad right-of-way is often left in such a condition after logging operations that it is a difficult matter to prevent fire starting, even when the greatest precaution is observed. Several roads are now working with the State Foresters to accomplish this result; notably the Chicago & Northwestern in the State of Wisconsin.

While the chief loss in timber is due to fire, other causes contribute largely to the prodigious waste which has accompanied our use of the forest. One-fourth of the standing timber is left or otherwise lost in logging. The boxing of long leaf pine for turpentine has destroyed one-fifth of the forests worked. The loss in the mill is from one-third to two-thirds of the timber sawed. The loss in the mill product through seasoning and fitting for use is from one-seventh to one-fourth. Great damage is done by insects to forests and forest products. An average of only 320 ft. of lumber is used for each 1,000 ft. which stood in the forest.

Of all the wood in every form now in use in the United States, decay, fire, insects and saltwater borers destroy not less than the equivalent of 8,000 million board ft. each year. Of these, decay is far the most destructive.

The first attempt in this country to prevent decay by treating wood was in 1838 on the Northern Central Railroad. About a mile of track was laid with treated ties, but owing to the low first cost of the ties which were chestnut and oak and were delivered to the railroad at fourteen or sixteen cents apiece, this did not develop into a permanent industry.

In 1880 for the first time the United States census undertook to ascertain what remained of our timber resources; it was found that they had been very rapidly depleted. Realizing the importance of the question the American Society of Civil Engineers appointed a committee to report upon

the best methods of preserving wood, in order to lengthen its life. This committee was appointed in 1880 and after five years of work presented its report in 1885. This was followed by the movement which has culminated in the present large wood preservation industry of the country.

In the year 1910, 97,500,000 cu. ft. of timber was treated. Most of this material consisted of cross-ties. Sixty-three million cu. ft., which constituted about 65 per cent. of the total, were treated with the creosote treatment and the remainder with zinc chloride and zinc creosote treatment in the order named.

In the United States the science of forestry is still in the formation stage. Knowledge of the characteristics and requirements of the many species of trees composing the forests is limited; the total amount and distribution of forest wealth is not accurately known; and methods of administration are not yet settled, but are subject to frequent change. In Europe, on the contrary, forestry as practiced to-day is the result of centuries of gradual evolution, and is consequently thoroughly systematized and its methods firmly established (note G). Foreign silvicultural methods are not usually applicable without change, but the general systems have been adapted with success to conditions in this country, and should be still more widely used.

A striking point concerning forestry abroad is the important part taken by the State in the management of communal and private as well as of the State forests, and the considerably greater returns obtained under State management. All communal forests are subject to some form of State supervision, and many of them are managed precisely as if they were State property.

Private forests necessary for the protection of water sheds or the welfare of the general public are also subject to State control; they cannot be cleared, cutting must be done as prescribed by the State, and all cuttings must be reforested. Other private forests not necessary for protective purposes can usually be managed as the owner desires, but co-operation with the State in the management of such forests is common.

With a few exceptions comparatively little attention has been paid by the railroads to forestry. Tree plantations (note H) have been started in a number of cases, some of which have been on a large scale, but for the most part experimentally. Forest planting in some cases may be desirable when a railroad has waste land for which it has no particular use. It is a good object lesson to the farmers, and if the plantations are successful they will net a fair return on the investment and furnish a limited supply of ties and timber for the future.

It should be observed, however, that it would not be practicable for the individual roads to plant enough trees to supply their timber requirements, and further the critical period of scarcity and high prices would come before any of the trees so planted would reach maturity.*

*Refer to the paper entitled "Preliminary Report of Sub-Committee on Future Policy of Railroads with Reference to the Tie Supply," which appeared in the ninth volume (1908) of the Proceedings of the American Railway Engineering and Maintenance of Way Association.

The information* assembled by the Committee on Ties of this Association in 1910 shows what has been done by the railroads in the way of tree planting; the situation is very little changed at the present time and in the opinion of those best able to judge, relief from this source is very uncertain.

If the railroads wish to provide against future scarcity and excessive prices with any degree of certainty it will be necessary for them to actively engage in forestry operations having for their purpose the management of mature timber lands and the cultivation and reforestation of the cut-over lands within the forest area. This is an individual problem with every road, but generally speaking it is the only sound policy which will provide for the future requirements fifteen or twenty years hence.

Some of the railroads have now undertaken to preserve the timber lands which they acquired through land grants and otherwise. The Southern Pacific in Northern California and Southern Oregon still have quite large areas of good timber from which they can cut mature trees. The Northern Pacific has been co-operating with the Government for some years with a view to finding how best to handle their western holdings and provide a source of tie supply at the eastern end of their lines. In the East, the Delaware & Hudson have put about one hundred thousand acres in the Adirondacks under management.

RECOMMENDATION FOR NEXT YEAR'S WORK.

(a) Investigation of the forest fire laws of the different States as they apply to railroads.

(b) The best methods to be used by railroads to reduce risk from fires caused by locomotives.

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LIST OF FIGURES.

Fig. 1. Opposite page 180. Loco cite.

Fig. 2. Opposite page 55 (Fig. 3) Vol. 1, Report of the National Conservation Commission, 1909.

COAL AND FUEL OIL RESOURCES.

The Sub-Committee dealing with the above subject has read and examined a large mass of papers and various data, and it is believed that the following report will prove of value to the Association.

This subject has not heretofore been covered by the Association. The article relating to relative tests of oil as compared to coal is valuable and probably new to 80 per cent. of the members. The standard specifications proposed by Mr. McAuliffe are worthy of endorsement by the Association; the Government specifications are also valuable information.

The statistics given in the report are accurate and valuable information.

The essence of the report on this subject is that portion relating to "Methods of preventing or lessening waste in the petroleum industry." This paper is by Mr. David T. Day, of the United States Geological Survey, and is worthy of a great deal of earnest consideration.

*ADVANTAGES OF OIL AS FUEL COMPARED TO COAL.

The principal advantages incident to burning oil as compared with coal can be summed up as follows:

(1) Cost. This item depends entirely on relative price at mine and well, plus freight to point of consumption. In computing freight haul, tariff rates must govern when moved over foreign lines the actual cost of moving (not including what is known as fixed charges) ordinarily used in computing cost over home rails. In making these computations the fact that from 1,000 to 1,500 lbs. of oil equal 2,000 lbs. of coal must be taken into account.

(2) Decreased cost of handling oil from cars to engines with practically no loss by depreciation due to such handling, all coal suffering badly in passage through coaling plants of whatever type.

(3) The losses by evaporation suffered by coal do not apply to oil, neither does loss by theft in transit occur, oil reaching engine tenders unimpaired as to quality and undiminished in quantity.

(4) Saving of time at terminals and increased mileage per engine, it being unnecessary to cut engines out for flue cleaning; the oil capacity

*From address by Mr. Eugene McAuliffe before International Railway Fuel Association.

of tender approximating 150 per cent. of that of coal, making longer runs possible.

(5) Freedom from physical failure of firemen in extreme hot weather, the fireman's work being actually lighter than that of the engineer.

(6) Stability of delivery, oil being unaffected by labor conditions which has made the production of coal in some sections so uncertain as to necessitate the storage of immense quantities of coal at great expense, this condition occurring at frequent intervals.

(7) Greater cleanliness in handling passenger trains with almost absolute immunity from right-of-way fires, saving the cost of fire-guards, and reducing also claim department losses.

The drawbacks to the use of oil have been in the direction of uncertain supply. The expense of equipping the average locomotive to burn oil approximates $800; the cost of constructing steel storage tanks of large capacity approximating 25c per barrel. The necessary terminal facilities, however, cost but about 50 per cent. of the amount required to handle coal. With coaling facilities usually in place, however, the oil facilities when installed, represent a duplication. Frequently, before the producer is able to judge his production sufficiently well to warrant the making of definite contracts, large quantities of "pot" oil must be sacrificed for want of storage or market facilities. After the production is reasonably well determined, an interval of time is necessary to transform locomotives, these factors being embarrassing both to the oil producer and the railroad consumer. With the development of new fields and the purchase of large numbers of cars, together with the increased installation of oil-burning apparatus, this condition will grow less burdensome in the future than it has been in the past.

The relative cost of oil and coal as a locomotive fuel is governed entirely by local conditions. Any road contemplating the use of oil must test the grade of oil or residuum it expects to burn against the grade of coal for which it is to be substituted. Different coals grade within greater extremes than do oils, which fact, if proper allowance is made for water and sediment in the case of crude oil purchases, will show a limited variation in the number of British thermal units per pound of fuel.

*PETROLEUM AS A LOCOMOTIVE FUEL.

What may be taken as an indication that petroleum, as a locomotive fuel, is coming into a greater degree of prominence than has hitherto been accorded this important subject, is the very complete equipment for handling and using this fuel on the Cascade Division of the Great Northern Railway. The significance of this work is all the more marked owing to the fact that the region in which this division is located is convenient to a plentiful supply of high-grade coal and is more than a thousand miles distant from the source of oil supply—the direct opposite of the situation which had so much to do with the successful development of locomotive oil-burning apparatus in the Southwest. The very stumbling blocks to the satisfactory operation of its Cascade Division by means of coal-burning locomotives, it appears, will prove a vast boon to the Great Northern, not only from the fact that by the use of fuel oil will these difficulties be circumvented, but at the same time there is given promise of a sufficient saving in the cost of operation to cover the entire cost of the fuel oil receiving, storage and handling facilities, approximately $300,000, during the first year of their use.

One of the conspicuous features prompting the change from coal to oil in this instance was the constant danger of fire both to the vast forest preserves through which the line passes, and to the numerous timber

*Editorial from Railway and Engineering Review, December 9, 1911.

snowsheds which the road maintains in this locality. Great as was the relief to be sought from the damages attending the use of coal on account of fires, the earliest investigations showed the possibility of material savings in the cost of the fuel itself, irrespective of the distance from the source of supply. In addition there was recognized the possibility of reduced cost in handling and transporting the fuel, savings due to the elimination of losses following the exposure of coal to weather conditions, theft, etc., and the saving in time owing to the greater convenience of oil as compared with coal, besides which the advantage of being able to concentrate within a single motive power unit every ounce of power of which the locomotive, as a machine, is capable of developing and the general effect on the morale of the employes owing to the greater ease of firing and the improved conditions as to cleanliness, are items which argue strongly in favor of the use of oil. Other and more local factors adding to the difficulty of operation in this locality are heavy mountain grades and extreme weather conditions, through all of which the Great Northern has set itself the task of maintaining an efficient and dependable transcontinental service. The care with which the engineers of this road have investigated and perfected this work seems to insure a successful outcome, which, when it definitely materializes, will undoubtedly mark the beginning of a much wider application of this fuel in railway service than at present obtains.

*EVAPORATIVE TESTS—OIL AS FUEL.

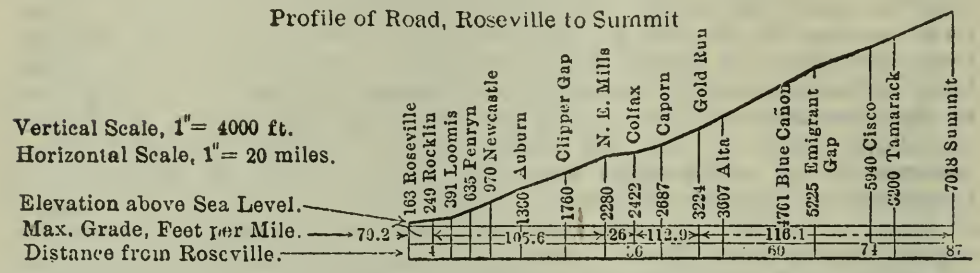
A large number of locomotive tests have been made by the Southern Pacific Company, covering the use of fuel oil as well as in comparison with coal. The accompanying table shows evaporative results on some of the most recent tests covering about the heaviest oil firing on the Southern Pacific in crossing the Sierra Nevada range. Comparisons of coal and oil from an economic standpoint are most interesting where the two fuels come in competition, and relative values must largely depend on the conditions and form of boilers under which either fuel is burned. Some engine boilers are better adapted for coal than oil, or vice versa, depending on construction. Comparisons therefore are to some degree a function of the boiler itself. This was gone into quite thoroughly when the locomotives were converted and a summary of the results is given as follows:

Type of Locomotive.	Number in Service.	Evaporation 2,000 lbs. Equivalent to Fuel Oil, Gals.
Eight-wheel	50	144
Ten-wheel	294	151
Mogul	176	146
Twelve-wheel	67	158
Consolidation	139	162
Atlantic	19	144
Mallet	17	No coal record

These figures are based on evaporative tests before and after conversion. The comparisons are with ordinary bituminous coal of about 13,350 b. t. u. The total number of locomotives accounted for above is 745, and the mean equivalent is 152 gals. or 3.62 bbls. of 42 gals., equivalent in heat value to 2,000 lbs. of coal. The average equivalent figures in the table cover much careful work and are based on equivalent evaporative results from many service tests. It should be borne in mind that the figures are

*Extract from a paper read by Mr. Howard Stillman before the American Society of Mechanical Engineers.

DATA FROM EVAPORATION TESTS OF LOCOMOTIVES, SACRAMENTO DIVISION, SOUTHERN PACIFIC COMPANY.



Class of engine	10 wheel	Consolidation	Mallet consolidation
Service	Passenger	Freight	Freight
Date of test	May 21 and 26, 1908	June 9 and 11, 1909	Nov. 6 and 8, 1909
Number of single trips in test	2	2	2
Total time of test	17 hr. 39 min.	21 hr. 23 min.	29 hr. 2 min.
Actual running time	13 hr. 55 min.	12 hr. 59 min.	18 hr. 11 min.
Miles run	315	174	174
Average steam pressure (gage), lb	196.0	196.1	194.5
Smoke box temperature, deg. fahr	797	738.5	451.3
Total gal. water evaporated	44147	48103	91087
Total lb. water evaporated	367642	400858	759058
Total gal. oil burned	3951.6	4328.4	7692.1
Total lb. oil burned	31613	34627	61537
Equivalent evaporation, lb. water per lb. oil	14.14	13.95	15.04
Lb. water evaporated per sq. ft. heating surface per hr	8.698	8.809	6.392
Lb. oil burned per sq. ft. heating surface per hr	0.748	0.761	0.518
Number of cars in train	7	14.5	24.5
Weight of train, tons	342	481	1056
Gross ton mileage	107730	83694	183744
Gal. water evaporated per 1000 ton mi.	409.79	574.75	495.73
Lb. water evaporated per 1000 ton mi.	3413	4790	4131
Gal. fuel oil burned per 1000 ton miles.	34.90	48.40	39.51
Lb. fuel oil burned per 1000 ton miles.	279.20	387.20	316.08
Boiler efficiency, per cent	73.84	72.83	78.52
Maximum i. h. p	1719	1470	2486
Mean i. h. p	1368	1222	2057
Dimensions of locomotive			
Engine no	231	2564	4001
Size of cylinders, in	22×28	22×30	26 and 40×30
Diameter of drivers, in	63	57	57
Total weight of locomotive, lb	203300	208000	425900
Weight on drivers, lb	160000	187000	394150
Weight of tender, lb	138070	134745	169765
Total heating surface, sq. ft	2994	3403	6394
Feed water heater, heating surface, sq. ft.			1221

NOTE.—Train weights are the average for the distance hauled and are exclusive of engine and tender. Tests made under ordinary service conditions. Engines unaided. In "water evaporated and oil burned per sq. ft. heating surface per hr.," the figures are for actual running time; the allowance of 15 gal. of oil and its equivalent in water is made per hr. while standing. In "gal. and lb. oil per 1000 ton mi.," a deduction is made of 15 gal. per hr. while standing and 3.5 per cent of oil for evaporating steam for atomizing oil. Quantity of oil burned corrected to normal temperature of 70 deg. fahr. All measuring instruments calibrated. Analysis of fuel: Kern River oil; gravity, 15.8 deg. Baumé; flash point, 230 deg. fahr.; fire point, 278 deg. fahr.; commercial weight, 8 lb. per gal.

from service tests and represent oil burned on the main line between terminals only, and not losses in transfer, handling, or firing up, etc. Our Accounting Department uses a figure of 168 gals. or 4 bbls. of oil, equivalent to one ton of coal. It may be said that with fuel oil, providing engines are burning it with a fair degree of efficiency, the quality of fuel is a constant factor. Poor or bad coal as accounting for engine failures drops from the delay report—"cleaning fires" is abolished.

*INSPECTION AND TESTS OF FUEL OIL.

SPECIFICATIONS OF FUEL OIL.

Inspection and Tests.

The matter of oil inspection, more particularly where crude oil is purchased, is an important one, and if any considerable volume of oil is purchased a competent, reliable inspector should be employed, one able to make the following determinations:

Flash Test.—By flash point is understood that temperature to which an oil must be heated to give off vapors, which, when mixed with air, produce an explosive mixture. The results of this test will vary according to the quantity of air over the surface of the oil, and whether this be moving or still; also according to the distance of the testing flame from the surface of the oil. Furthermore, the size of the flame, the length of its time of action, its form and dimensions, and, lastly, the manner of heating of the oil, will all influence the result.

Fire Test.—The fire test of an oil is the temperature at which it will give off vapors, which, when ignited, will burn continuously. It is made by continuing to heat the oil (the cover being removed in the case of a closed tester without slipping out the thermometer) at the same rate after the flash test is made, and noting the point as indicated above. The flame is extinguished by a piece of asbestos board and the heating discontinued. In the case of ordinary oils this point is from 10 degrees to 20 degrees Fahrenheit higher than the flash point.

Specific Gravity.—This is usually affected by the hydrometer; a hydrometer jar is four-fifths filled with the oil, a Baumé hydrometer introduced into it, and the depth read off to which the instrument sinks in the oil. This may be effected by placing a strip of white paper back of the jar and noting the point at which the meniscus of the oil touches the scale. The temperature of the oil is taken at the same time, and in case it be not 60 degrees Fahrenheit for every increase of 10 degrees Fahrenheit, subtract 1 degree Baumé from the hydrometer reading. The specific gravity may be found by the formula

$$\frac{140}{130 + \text{B. Deg.}}$$

representing the reading Baumé at 60 degrees Fahrenheit.

Shrinkage.—Frequently at small refineries, or where the residuum storage capacity is inadequate, oil is pumped into tank cars at a high temperature and when subsequently cooled to 60 degrees Fahrenheit, the loss from shrinkage is material. In the event that tank cars are partially filled in cold weather and the oil allowed to cool materially below 60 degrees Fahrenheit, care should be taken to see, when subsequently topped or filling is completed, that due allowance is made for increased volume incident to the expansion that will occur if the temperature of the oil is increased, a variation of 20 degrees Fahrenheit resulting in an expansion of approximately 1 per cent. For these reasons that feature of the inspection rules (set forth below) covering the shrinkage should be carefully observed.

*From address by Mr. Eugene McAuliffe before International Railway Fuel Association.

Water Determination.—The matter of determining the amount of water and sediment contained in crude oil, particularly when purchased from wells in a water-making field, or storage oil, when stored in earthen tanks subject to additions of water and sediment test set forth in the standard specifications.

Standard Specifications.

The following basis for standard specifications covering the purchase of fuel oil by RAILROAD companies will quite generally cover both crude and residuum purposes.

General Requirements.—Fuel oil to be distilled or reduced petroleum, free from sand or other solid matter that will impede or prevent free handling through ordinary-sized pumps, pipes or burners; to be of a viscosity that will permit of its being handled freely at a temperature of 60 degrees Fahrenheit. Whenever practicable, all free water must be drawn from working tanks before delivery. Swing pipes in working tanks must be adjusted to prevent, as far as possible, free water entering into delivery pumps or lines.

Sampling.—With full length thief. One sample will be taken from each car promptly after being unloaded, with a thief having automatic valve at lower end, which closes at instant thief touches bottom of car, the theory of this thief being to cut out a section of the fluid. When taking sample, thief should be lowered slowly and the upper end must have free outlet for air which thief contains when it is inserted into the oil, thus to admit of liquid replacing the air, without creating undue motion, suction or pressure at the bottom.

Testing Samples.—Same to permit of the use of gasoline or Centrifuge methods, as follows:

Gasoline Method.—Samples should be thoroughly shaken and mixed; then 50 cubic centimeters of sample placed in a 100 centimeter graduated glass cylinder, an equal quantity of not less than 68 degrees gasoline should be mixed with the sample in the graduated glass, the combined mixture of oil and gasoline should then be thoroughly shaken and sample heated to a temperature of from 120 degrees to 130 degrees Fahrenheit and allowed to stand for from three to six hours, the actual per cent. of water equal to twice the per cent. shown in the graduated glass.

Centrifuge Method.—Samples should be thoroughly shaken and mixed; then 100 cubic centimeters of sample placed in a 200-centimeter graduated glass cylinder. An equal quantity of not less than 68 degrees gravity gasoline should be mixed with the sample in the graduated glass; then glass placed in machine and the machine run full speed for five minutes, when reading should be taken, and machine then run for another five minutes and second reading taken; if on second reading there is any increase over first reading the machine should be run for another five minutes, making a total of fifteen minutes, when final reading should be taken, the per cent. of water doubled as before.

Percentage of water and sediment should be taken by representatives of seller and buyer, and tickets exchanged showing the total percentage of water and sediment which each car contains. The buyer shall be entitled to deduct all water and sediment in excess of one-half of one per cent. under the usual tests, and may refuse to accept or move cars containing in excess of 3 per cent. water and sediment.

In order to facilitate the movement of cars, the representatives of buyer and seller may, from time to time, take samples of oil from the filling lines as cars are being loaded, for the purpose of determining approximately the quality and condition of the oil being delivered, and may, for their personal information or for account of their principals, keep records of such samples.

Adjusting for Temperature.—Rack men and inspectors will regulate the filling of cars, being governed by the temperature of the oil at the time it is loaded. If cars are partially filled in very cold weather, care should be taken not to allow the oil to rise in the dome when topping or refilling is done, care being taken to see that sufficient room is left for possible expansion. When oil is placed in the car at a temperature above 60 degrees Fahrenheit an allowance of 1 per cent. in volume for each 20 degrees Fahrenheit above 60 degrees Fahrenheit should be made, i. e., 100 gallons on each tank car of 10,000 capacity.

Fire Test.—Buyer may refuse to accept any fuel oil showing a fire point less than 120 degrees Fahrenheit when tested by the open-cup Tagliabue method, namely: Heating the oil at the rate of 2 degrees per minute, test flame to be applied every 2 degrees as temperature of oil is raised, beginning at 60 degrees Fahrenheit.

Gravity.—Buyer may refuse to accept fuel oil of less than 15 degrees or more than 30 degrees Baumé gravity.

Tank Cars.—Tank cars furnished must be in good order and such cars must be provided with caps and valves that can be readily adjusted. Tank cars must be reasonably clean and free from deposits of dirt, sand sediment or other material that will appreciably affect the tests of the quality of the oil. Seller may refuse to accept cars furnished that are not in the condition above specified, unless instructed to fill cars at buyer's risk as to loss or quality of oil. Turning oil into cars at racks will be understood to be an acceptance on the part of the seller.

Receipts.—In the event that the buyer maintains a representative for the purpose of inspecting shipments of oil furnished under this contract, such representative will, when tank cars have been loaded, samples taken, outlet caps and manheads placed, immediately sign receipt furnished by the representative of the seller, showing: (1) number of refinery, well, or number of storage tank loading same; (2) station from which car is billed; (3) car number and initial; (4) car capacity shown in Interstate Commerce Commission tariffs; (5) actual capacity as cars are loaded after allowance for expansion or contraction has been made as provided for in rules governing adjustment for temperature.

GOVERNMENT FUEL OIL SPECIFICATIONS.

In consequence of the success that has attended the use of heating-value specifications in buying and selling coal, there has arisen a demand for similar specifications, based on careful tests, to govern the purchase of fuel oils and the refined products of petroleum. The bureau of mines has therefore issued technical paper No. 3, by Mr. Irving C. Allen, on "Specifications for the purchase of fuel oil for the Government," with directions for sampling oil and natural gas.

The general specifications for the purchase of fuel oil are given as follows:

In determining the award of a contract, consideration will be given to the quality of the fuel offered by the bidders, as well as the price, and should it appear to be to the best interest of the government to award a contract at a higher price than that named in the lowest bid or bids received, the contract will be so awarded.

Fuel oil should be either a natural homogeneous oil or a homogeneous residue from a natural oil; if the latter, all constituents having a low flash point should have been removed by distillation; it should not be composed of a light oil and a heavy residue mixed in such proportions as to give the density desired.

It should not have been distilled at a temperature high enough to burn it, nor at a temperature so high that flecks of carbonaceous matter began to separate.

It should not flash below 60 degrees Centigrade (140 degrees Fahrenheit) in a closed Abel-Pensky or Pensky-Martens tester.

Its specific gravity should range from 0.85 to 0.96 at 15 degrees Centigrade (59 degrees Fahrenheit); the oil should be rejected if its specific gravity is above 0.97 at that temperature.

It should be mobile, free from solid or semi-solid bodies, and should flow readily, at ordinary atmospheric temperatures and under a head of 1 foot of oil, through a 4-in. pipe 10 ft. in length.

It should not congeal nor become too sluggish to flow at 0 degrees Centigrade (32 degrees Fahrenheit).

It should have a calorific value of not less than 10,000 calories per gram (18,000 B. T. U. per lb.), 10,250 calories to be the standard. A bonus is to be paid or a penalty deducted according to the method stated under section 21, as the fuel oil delivered is above or below this standard.

It should be rejected if it contains more than two per cent. water.

It should be rejected if it contains more than one per cent. sulphur.

It should not contain more than a trace of sand, clay or dirt.

Each bidder must submit an accurate statement regarding the fuel oil he proposes to furnish. This statement should show: The commercial name of the oil; the name or designation of the field from which the oil is obtained; whether the oil is a crude oil, a refinery residue or a distillate; the name and location of the refinery, if the oil has been refined at all.

The fuel oil is to be delivered f. o. b. cars or vessel, according to the manner of shipment, at such places, at such times, and in such quantities as may be required, during the fiscal year.

Should the contractor, for any reason, fail to comply with a written order to make delivery, the government is to be at liberty to buy oil in the open market and charge against the contractor any excess of price, above the contract price, of the fuel oil so purchased.

Complete copies of these specifications may be obtained from the director of the bureau of mines, Washington, D. C.

*METHODS OF PREVENTING OR LESSENING WASTE IN THE PETROLEUM INDUSTRY.

CHECKING UNNECESSARY PRODUCTION.

At present more petroleum is being produced than is necessary for the legitimate demands of the industry. Within ten years the present fields will be unable profitably to produce enough for these legitimate requirements. Inasmuch as the lands now owned by private interests are leased by rival concerns, it is impossible to prevent each rival from producing petroleum as rapidly as he desires. The only direction in which production can be checked is with the petroleum contained in public lands. Offering such public land for entry at a nominal price is nothing more than temptation to the private citizen to waste petroleum by overproduction, since lands yielding hundreds of dollars per acre in this product can be obtained for a nominal sum. Every acre of public land believed to contain supplies of petroleum or natural gas should be withdrawn from every form of entry and should be subjected to an equitable system of lease. By this means undoubtedly a large amount of petroleum would be reserved for use when the supply becomes inadequate to industrial demands. It should be noted that since the ad-

*From Government Report, "Production of Petroleum in 1910."

*PRODUCTION OF PETROLEUM IN THE UNITED STATES FROM 1859-1910, INCLUSIVE.

PRODUCTION OF PETROLEUM IN THE UNITED STATES, 1859-1910, INCLUSIVE, BY YEARS AND BY STATES, IN BARRELS OF 42 GALLONS.

Year.	Pennsylvania and New York.	Ohio.	West Virginia.	California.	Kentucky and Tennessee.	Colorado.	Indiana.	Illinois.
1859.....	2,000	.....	.....	.....	.....	.....	.....	.....
1860.....	500,000	.....	.....	.....	.....	.....	.....	.....
1861.....	2,113,609	.....	.....	.....	.....	.....	.....	.....
1862.....	3,056,690	.....	.....	.....	.....	.....	.....	.....
1863.....	2,611,309	.....	.....	.....	.....	.....	.....	.....
1864.....	2,116,109	.....	.....	.....	.....	.....	.....	.....
1865.....	2,497,700	.....	.....	.....	.....	.....	.....	.....
1866.....	3,597,700	.....	.....	.....	.....	.....	.....	.....
1867.....	3,347,300	.....	.....	.....	.....	.....	.....	.....
1868.....	3,646,117	.....	.....	.....	.....	.....	.....	.....
1869.....	4,215,000	.....	.....	.....	.....	.....	.....	.....
1870.....	5,260,745	.....	.....	.....	.....	.....	.....	.....
1871.....	5,205,234	.....	.....	.....	.....	.....	.....	.....
1872.....	6,293,194	.....	.....	.....	.....	.....	.....	.....
1873.....	9,893,786	.....	.....	.....	.....	.....	.....	.....
1874.....	10,926,945	.....	.....	.....	.....	.....	.....	.....
1875.....	8,787,514	.....	.....	.....	.....	.....	.....	.....
1876.....	8,968,906	31,763	120,000	12,000	.....	.....	.....	.....
1877.....	13,135,475	29,888	172,000	13,000	.....	.....	.....	.....
1878.....	15,163,462	38,179	180,000	15,227	.....	.....	.....	.....
1879.....	19,685,176	29,112	180,000	19,858	.....	.....	.....	.....
1880.....	26,027,631	38,940	179,000	40,552	.....	.....	.....	.....
1881.....	27,376,509	33,867	151,000	99,862	.....	.....	.....	.....
1882.....	30,053,500	39,761	128,000	128,636	.....	.....	.....	.....
1883.....	23,128,389	47,632	126,000	142,857	4,755	.....	.....	.....
1884.....	23,772,209	90,081	90,000	262,000	4,148	.....	.....	.....
1885.....	20,776,041	661,580	91,000	325,000	5,164	.....	.....	.....
1886.....	25,798,000	1,782,970	102,000	377,145	4,726	.....	.....	.....
1887.....	22,356,193	5,022,632	145,000	678,572	4,791	76,295	.....	.....
1888.....	16,488,668	10,010,868	119,448	690,333	5,096	297,612	.....	.....
1889.....	21,487,435	12,471,466	544,113	203,220	5,400	316,476	33,375	1,400
1890.....	28,458,208	16,124,656	492,578	307,360	6,000	368,842	63,496	900
1891.....	33,009,236	17,740,301	2,406,218	323,600	9,000	665,482	136,634	675
1892.....	28,422,377	16,362,921	3,810,086	385,049	6,500	824,000	698,068	521
1893.....	20,314,513	16,249,769	8,445,412	470,179	3,000	594,390	2,335,293	400
1894.....	19,019,990	16,792,154	8,577,624	705,969	1,500	515,746	3,688,666	300
1895.....	19,144,390	19,545,233	8,120,125	1,208,482	1,500	438,232	4,386,132	200
1896.....	20,584,421	23,941,169	10,019,770	1,252,777	1,680	361,450	4,680,732	250
1897.....	19,262,066	21,560,515	13,090,045	1,903,411	322	384,934	4,122,356	500
1898.....	15,948,464	18,738,708	13,615,101	2,257,207	5,568	444,383	3,730,907	360
1899.....	14,374,512	21,142,108	13,910,630	2,642,095	18,280	390,278	3,848,182	360
1900.....	14,559,127	22,362,730	16,195,675	4,324,484	62,259	317,385	4,874,392	200
1901.....	13,831,996	21,648,083	14,177,126	8,786,330	137,259	460,520	5,757,086	250
1902.....	13,183,610	21,014,231	13,513,345	13,984,268	185,331	396,901	7,480,896	200
1903.....	12,518,134	20,480,286	12,899,395	24,382,472	554,286	483,925	9,186,411	.....
1904.....	12,239,026	18,876,631	12,644,686	29,649,434	998,284	501,763	11,339,124	.....
1905.....	11,554,777	16,346,660	11,578,110	33,427,473	1,217,337	376,238	10,964,247	181,084
1906.....	11,500,410	14,787,763	10,120,935	33,098,598	1,213,548	327,582	7,673,477	4,397,050
1907.....	11,211,606	12,207,448	9,095,296	39,748,375	820,844	331,851	5,128,037	24,281,973
1908.....	10,584,453	10,858,797	9,523,176	44,854,737	[a] 727,767	379,653	3,283,629	33,686,238
1909.....	10,434,300	10,632,793	10,745,092	55,471,601	[a] 639,016	310,861	2,296,086	30,898,399
1910.....	9,848,500	9,916,370	11,751,871	73,010,560	[a] 468,774	239,794	2,159,725	33,143,362
Total.	718,292,662	397,658,065	217,059,857	375,302,723	7,112,135	9,804,593	97,866,951	126,593,490

[a] No production in Tennessee recorded.

*From Government Report, "Production of Petroleum in 1910."

PRODUCTION OF PETROLEUM IN THE UNITED STATES, 1859-1910, BY YEARS AND BY STATES, IN BARRELS OF 42 GALLONS—CONTINUED.

Year.	Kansas.	Texas.	Missouri.	Oklahoma.	Wyoming.	Louisiana.	United States.	Total value.
1859							2,000	$32,000
1860							500,000	4,800,000
1861							2,113,609	1,035,668
1862							3,056,690	3,209,525
1863							2,611,309	8,225,663
1864							2,116,109	20,896,576
1865							2,497,700	16,459,853
1866							3,597,700	13,455,398
1867							3,347,300	8,066,993
1868							3,646,117	13,217,174
1869							4,215,000	23,730,450
1870							5,260,745	20,503,754
1871							5,205,234	22,591,180
1872							6,293,194	21,440,503
1873							9,893,786	18,100,464
1874							10,926,945	12,647,527
1875							8,787,514	7,368,133
1876							9,132,669	22,982,822
1877							13,350,363	31,788,566
1878							15,396,868	18,044,520
1879							19,914,146	17,210,708
1880							26,286,123	24,600,638
1881							27,661,238	23,512,051
1882							30,349,897	23,631,165
1883							23,449,633	25,740,252
1884							24,218,438	20,476,924
1885							21,858,785	19,193,694
1886							28,064,841	20,028,457
1887							28,283,483	18,856,606
1888							27,612,025	17,950,353
1889	500	48	20				35,163,513	26,963,340
1890	1,200	54	278				45,823,572	35,365,105
1891	1,400	54	25	30			54,292,655	30,526,553
1892	5,000	45	10	80			50,514,657	25,906,463
1893	18,000	50	50	10			48,431,066	28,932,326
1894	40,000	60	8	130	2,369		49,344,516	35,522,095
1895	44,430	50	10	37	3,455		52,892,276	57,691,279
1896	113,571	1,450	43	170	2,878		60,960,361	58,518,709
1897	81,098	65,975	19	625	3,650		60,475,516	40,929,611
1898	71,980	546,070	10		5,475		55,364,233	44,193,359
1899	69,700	669,013	132		5,560		57,070,850	64,603,904
1900	74,714	836,039	[a] 1,602	6,472	5,450		63,620,529	75,752,691
1901	179,151	4,393,658	[b] 2,335	10,000	5,400		69,389,194	66,417,335
1902	331,749	18,083,658	[a] 757	37,100	6,253	548,617	88,766,916	71,178,910
1903	932,214	17,955,572	[a] 3,000	138,911	8,960	917,771	100,461,337	94,694,050
1904	4,250,779	22,241,413	[a] 2,572	1,366,748	11,542	2,958,958	117,080,960	101,175,455
1905	[c] 12,013,495	28,136,189	[a] 3,100	[d]	8,454	8,910,416	134,717,580	84,157,399
1906	[c] 21,718,648	12,567,897	[a] 3,500	[d]	[e] 7,000	9,077,528	126,493,936	92,444,735
1907	2,409,521	12,322,696	[a] 4,000	43,524,128	[f] 9,339	5,000,221	166,095,335	120,106,749
1908	1,801,781	11,206,464	[a] 15,246	45,798,765	[f] 17,775	5,788,874	178,527,355	129,079,184
1909	1,263,764	9,534,467	[a] 5,750	47,859,218	[f] 20,056	3,059,531	183,170,874	128,328,487
1910	1,128,668	8,899,266	[a] 3,615	52,028,718	[f] 115,430	6,841,395	209,556,048	127,896,328
Total.	46,551,363	147,460,188	46,082	190,771,142	239,046	44,149,567	2,378,907,864	2,040,808,758

[a] Includes the production of Michigan.
[b] Includes production of Michigan and small production in Oklahoma.
[c] Includes production of Oklahoma.
[d] Included with Kansas.
[e] Estimated.
[f] Includes the production of Utah.

vance copies of this report appeared in the public press, the petroleum producers of Oklahoma have arranged to reduce production in that state.

BETTER COMBUSTION.

The use of petroleum as a form of power is justified on the Pacific Coast, provided attention is given to securing the maximum amount of power per unit of oil. This is not consistent with burning oil under stationary boilers for the production of steam, but prompt study should be given to the development of internal-combustion engines capable of using crude petroleum or, more particularly, less valuable residuum. It should be noted that private enterprise has already done much for the successful solution of this problem.

RANK OF PETROLEUM-PRODUCING STATES, WITH VALUE OF PRODUCTION AND PERCENTAGE OF EACH, IN 1909 AND 1910.

1909				1910			
State.	Rank.	Value.	Percentage.	State.	Rank.	Value.	Percentage.
California	1	$30,756,713	23.97	California	1	$35,749,473	27.95
Illinois	2	19,788,864	15.42	Oklahoma	2	19,922,660	15.58
West Virginia	3	17,642,283	13.75	Illinois	3	19,669,383	15.38
Oklahoma	4	17,428,990	13.58	West Virginia	4	15,720,184	12.29
Pennsylvania	5	15,424,554	12.02	Pennsylvania	5	11,908,914	9.31
Ohio	6	13,225,377	10.31	Ohio	6	10,651,568	8.33
Texas	7	6,793,050	5.30	Texas	7	6,605,755	5.16
Louisiana	8	2,022,449	1.58	Louisiana	8	3,574,069	2.80
Indiana	9	1,997,610	1.55	Indiana	9	1,568,475	1.21
New York	10	1,878,217	1.46	New York	10	1,414,668	1.11
Kentucky	11	518,299	.40	Kansas	11	444,763	.35
Kansas	12	491,633	.38	Kentucky	12	324,684	.25
Colorado	13	318,162	.25	Colorado	13	243,402	.20
Wyoming	14	42,286	.03	Wyoming	14	98,330	.08
Missouri	15			Utah	15		
Michigan	16			Michigan	16		
Utah	17			Missouri	17		
Total		128,328,487	100.00	Total		127,896,328	100.00

RANK OF PETROLEUM-PRODUCING STATES, WITH QUANTITY AND PERCENTAGE PRODUCED BY EACH, IN 1909 AND 1910, IN BARRELS.

1909				1910			
State.	Rank.	Quantity	Percentage.	State.	Rank.	Quantity.	Percentage.
California	1	55,471,601	30.28	California	1	73,010,560	34.84
Oklahoma	2	47,859,218	26.13	Oklahoma	2	52,028,718	24.83
Illinois	3	30,898,339	16.87	Illinois	3	33,143,362	15.82
West Virginia	4	10,745,092	5.87	West Virginia	4	11,751,871	5.61
Ohio	5	10,632,793	5.80	Ohio	5	9,916,370	4.73
Texas	6	9,534,467	5.21	Texas	6	8,899,266	4.25
Pennsylvania	7	9,299,403	5.08	Pennsylvania	7	8,794,662	4.20
Louisiana	8	3,059,531	1.67	Louisiana	8	6,841,395	3.26
Indiana	9	2,296,086	1.25	Indiana	9	2,159,725	1.03
Kansas	10	1,263,764	.69	Kansas	10	1,128,668	.54
New York	11	1,134,897	.62	New York	11	1,053,838	.50
Kentucky	12	639,016	.35	Kentucky	12	468,774	.22
Colorado	13	310,861	17	Colorado	13	239,794	.12
Wyoming	14	25,806	01	Wyoming	14	119,045	.05
Michigan	15			Utah	15		
Missouri	16			Michigan	16		
Utah	17			Missouri	17		
Total		183,170,874	100.00	Total		209,556,048	100.00

PREVENTION OF WASTE IN EXTRACTION AND IN USE.

Legislation tending to the capping of gas wells in petroleum fields to preserve the pressure and to prevent the unnecessary encroachment of water, should be extended to all states where petroleum is produced. After the practical exhaustion of the field by this encroachment of water, the remaining petroleum can frequently be washed into smaller but still profitable pools—a system which is already intelligently used in this country.

DISCOVERY AND DEVELOPMENT OF SUBSTITUTES.

Alcohol from grain, potatoes and waste products can be used in the place of petroleum as an illuminant and for power in place of gasoline

TOTAL QUANTITY AND VALUE OF PETROLEUM PRODUCED IN THE UNITED STATES AND THE AVERAGE PRICE PER BARREL IN 1909 AND 1910, BY STATES, IN BARRELS.

State.	1909			1910		
	Quantity.	Value.	Average price per barrel.	Quantity.	Value.	Average price per barrel.
California	55,471,601	$30,756,713	$0.554	73,010,560	$35,749,473	$0.490
Colorado	310,861	318,162	1.023	239,794	243,402	1.015
Illinois	30,898,339	19,788,864	.640	33,143,362	19,669,383	.593
Indiana	2,296,086	1,997,610	.870	2,159,725	1,568,475	.726
Kansas	1,263,764	491,633	.389	1,128,668	444,763	.394
Kentucky	639,016	518,299	.811	468,774	324,684	.693
Louisiana	3,059,531	2,022,449	.661	6,841,395	3,574,069	.522
Michigan, Missouri	5,750	7,830	1.362	3,615	4,794	1.326
New York	1,134,897	1,878,217	1.655	1,053,838	1,414,668	1.342
Ohio	10,632,793	13,225,377	1.244	9,916,370	10,651,568	1.074
Oklahoma	47,859,218	17,428,990	.364	52,028,718	19,922,660	.383
Pennsylvania	9,299,403	15,424,554	1.659	8,794,662	11,908,914	1.354
Texas	9,534,467	6,793,050	.712	8,899,266	6,605,755	.742
Utah, Wyoming	20,056	34,456	1.718	115,430	93,536	.810
West Virginia	10,745,092	17,642,283	1.642	11,751,871	15,720,184	1.338
Total	183,170,874	128,328,487	.701	209,556,048	127,896,328	.610

WORLD'S PRODUCTION OF CRUDE PETROLEUM, 1906-1910, BY COUNTRIES.

Country.	1906	1907	1908	1909	1910			
					Rank.	Barrels.	Metric tons.	Per cent of total production.
United States	126,493,936	166,095,335	178,527,355	183,170,874	1	209,556,048	27,940,806	63.99
Russia	58,897,311	61,850,734	62,186,447	65,970,350	2	70,336,574	9,378,210	21.48
Galicia	5,467,967	8,455,841	12,612,295	14,932,799	3	12,673,688	1,762,560	3.87
Dutch East Indies	8,180,657	9,982,597	10,283,357	11,041,852	4	11,030,620	1,495,715	3.37
Roumania	6,378,184	8,118,207	8,252,157	9,327,278	5	9,722,958	1,352,289	2.97
India	4,015,803	4,344,162	5,047,038	6,676,517	6	6,137,990	818,400	1.87
Mexico	.....	1,000,000	3,481,410	2,488,742	7	3,332,807	444,374	1.02
Japan	1,710,768	2,010,639	2,070,145	1,889,563	8	1,930,661	257,421	.59
Peru	536,294	756,226	1,011,180	1,316,118	9	1,330,105	177,347	.40
Germany	578,610	756,631	1,009,278	1,018,837	10	1,032,522	145,168	.32
Canada	569,753	788,872	527,987	420,755	11	315,895	42,119	.10
Italy	53,577	59,875	50,966	42,388	12	42,388	5,895	.02
Other	a 30,000	a 30,000	a 30,000	a 30,000	13	a 30,000	4,000	
Total	212,912,860	264,249,119	285,089,615	298,326,073	.....	327,472,256	43,824,304	100.00

a Estimated.

whenever the necessity arises. No practical substitute is known for mineral lubricating oils. Animal and vegetable oils are excluded as entirely too expensive. The production of artificial petroleum from various vegetable and animal waste products has received sufficient study to indicate the possibility of good results if scientific research is encouraged in this direction.

NECESSITY OF SCIENTIFIC RESEARCH.

The most practical recommendation seems to be the encouragement of scientific research in the study of the conditions of occurrence of petroleum in the earth, in order to lessen the expense of discovery of new pools. A second line of scientific research of even greater value should include fundamental studies of the nature of all kinds of petroleum, with a view to converting less valuable varieties into higher grades and to producing greater proportions of the absolutely necessary lubricating oils from crude petroleum. Such scientific study should be initiated at once to be of benefit when the present petroleum supply becomes inadequate.

TIME OF EXHAUSTION.

Regarding the limits of time within which the present supply will be exhausted, it is clear that considering the minimum quantity of petroleum in the United States as 15,000,000,000 barrels, and continuing the present rate of increase in production, the supply would be exhausted about 1935. If the present annual production were continued without increase, 90 years would be required to exhaust this estimated minimum quantity. A reasonable view of the situation makes it probable that the present annual rate of production will be increased slightly through the developments of Illinois, Oklahoma and California, but that within a very few years a marked decline will be noted, and this will continue with increasing value for the oil product and an insufficient quantity for the legitimate demands of the industry after another decade, and that the production, on a reduced scale, will continue for a long time, but in an amount unsatisfactory to industrial necessity, except as supplemented from new fields.

RECOMMENDATIONS.

Three conclusions are self-evident from this report:

(1) It is absolutely necessary for the preservation of an adequate supply of petroleum that all public lands where petroleum is probable should at once be withdrawn from entry.

(2) A general investigation of the conditions of accumulation of petroleum and its geographic distribution should be undertaken in order that the petroleum-bearing public lands may be selected.

(3) Fundamental scientific study of the nature of petroleum, especially with a view to securing the greatest yields of the most valuable constituents and even for transmuting one oil into another, is required for its most intelligent use.

*COAL FIELDS OF THE UNITED STATES.

The coal areas of the United States are divided, for the sake of convenience, into two great divisions—anthracite and bituminous.

The areas in which anthracite is produced are confined almost exclusively to the eastern part of Pennsylvania, and usually when the anthracite fields of the United States are referred to, those of eastern Pennsylvania are meant. These fields are included in the counties of Susquehanna, Lackawanna, Luzerne, Carbon, Schuylkill, Columbia, Northumberland, Dauphin and Sullivan, and underlie an area of about 480 square miles. In addition to these well-known anthracite fields of

*From Government Report, "Production of Coal in 1910."

Pennsylvania there are two small areas in the Rocky Mountain region where the coal has been locally anthracited, although the production from these districts has never amounted to as much as 100,000 tons in any one year. One of these localities is in Gunnison County, Colo., and the other in Santa Fe County, N. M. The coal, although only locally metamorphosed, is a true anthracite and of a good quality. In previous years some coal, which was classed as anthracite, was mined and sold in New England. The productive area was confined to the eastern part of Rhode Island and the counties of Bristol and Plymouth in Massachusetts. In 1909, redevelopment of the old mines at Portsmouth was in progress, and the result of rehabilitating these properties and of utilizing the product will be watched with interest.

The bituminous and lignite fields are scattered widely over the United States and include an area of something over 496,000 square miles. The previous classification of these coal areas published in earlier volumes of the report, "Mineral Resources of the United States," has been changed as a result of conferences among the geologists working under Marius R. Campbell on the economic geology of coal. The areas are divided, primarily, into six provinces, as follows:

(1) The eastern province, which includes all of the bituminous areas of the Appalachian region; the Atlantic Coast region, which includes the Triassic fields near Richmond and Deep River and Dan River fields of North Carolina, and also the anthracite region of Pennsylvania. (2) The Gulf province, which includes the lignite fields of Alabama, Mississippi, Louisiana, Arkansas and Texas. (3) The interior province, which includes all the bituminous areas of the Mississippi Valley region and the coal fields of Michigan. This province is subdivided into the eastern region, which embraces the coal fields of Illinois, Indiana and western Kentucky; the western region, which includes the fields of Iowa, Missouri, Nebraska, Kansas, Arkansas and Oklahoma; and the southwestern region, which includes the coal fields of Texas. The Michigan fields are designated as the northern region of the interior province. (4) The northern, or Great Plains, province, which includes the lignite areas of North Dakota and South Dakota and the bituminous and subbituminous areas of northeastern Wyoming and of northern and eastern Montana. (5) The Rocky Mountain province, which includes the coal fields of the portions of Montana and Wyoming which are in the mountainous districts of those states, and all the coal fields of Utah, Colorado and New Mexico. (6) The Pacific Coast province, which includes all of the coal fields of California, Oregon and Washington.

According to the revised estimates the supply of coal in the ground when mining began was 3,076,204,000,000 short tons, of which 1,922,979,000,000 are considered to be easily accessible, and 1,153,225,000,000 short tons to be either so deep or the beds so thin that they are accessible only with difficulty. Classified according to the character of the coal, the original supply consisted of 21,000,000,000 short tons of anthracite, 1,661,457,000,000 tons of bituminous coal, 650,157,000,000 tons of sub-bituminous coal, and 743,590,000,000 tons of lignite. The total production at the close of 1910 was 8,243,351,259 short tons, which, including the loss involved in the mining and preparation of the coal, represents an exhaustion of 13,395,000,000 tons. The original supply, less the exhaustion at the close of 1910, leaves as the apparent supply still available 3,062,808,972,000 tons, or 99.6 per cent. of the original supply, or in other words, in all the time since coal mining began in the United States, the draft upon the original supply, including loss in mining, has amounted to less than one-half of one per cent. The annual rate of exhaustion at the present time, as represented by the production of 1910, is 0.025 of one per cent. of the supply. *The quantity of coal still in the ground at the close of 1910 was 6,000 times the production of that year.*

COAL PRODUCTION OF THE UNITED STATES IN 1910, BY STATES AND TERRITORIES IN SHORT TONS.

State or Territory.	Loaded at mines for shipment	Sold to local trade and used by employees.	Used at mines for steam and heat.	Made into coke.	Total quantity.	Total value.	Average price per ton.	Average number of days active.	Average number of employees.
Alabama	10,843,811	206,201	644,007	4,417,443	16,111,462	$20,236,853	$1.26	249	22,250
Arkansas	1,822,022	13,112	70,824	.....	1,905,958	2,979,213	1.56	128	5,568
California and Alaska	6,679	4,985	500	.....	12,164	33,336	2.74	189	19
Colorado	9,563,063	295,164	330,517	1,784,992	11,973,736	17,026,934	1.42	236	15,864
Georgia	94,330	776	2,760	79,379	177,245	259,122	1.46	265	386
Idaho	100	4,348	.....	.....	4,448	17,426	3.92	200	14
Illinois	41,818,730	2,666,614	1,400,352	14,550	45,900,246	52,405,897	1.14	160	72,645
Indiana	17,226,134	771,728	391,953	.....	18,389,815	20,813,659	1.13	229	21,878
Iowa	7,169,039	588,871	170,210	.....	7,928,120	13,903,913	1.75	218	16,666
Kansas	4,574,731	202,472	143,657	591	4,921,451	7,914,709	1.61	148	12,870
Kentucky	13,665,010	528,987	332,731	96,591	14,623,319	14,405,887	.99	221	20,316
Maryland	5,097,347	62,760	57,018	.....	5,217,125	5,835,058	1.12	270	5,809
Michigan	1,355,819	110,473	68,675	.....	1,534,967	2,930,771	1.91	211	3,575
Missouri	2,512,492	413,570	56,371	.....	2,982,433	5,328,285	1.79	154	9,691
Montana	2,657,087	101,613	124,751	37,519	2,920,970	5,329,322	1.82	239	3,837
New Mexico	2,720,641	40,428	46,048	701,204	3,508,321	4,877,151	1.39	283	3,585
North Dakota	269,037	119,377	10,627	.....	399,041	595,139	1.49	207	534
Ohio	31,958,985	1,684,444	560,290	5,949	34,209,668	35,932,288	1.05	203	46,641
Oklahoma	2,435,987	50,821	153,647	5,771	2,646,226	5,867,947	2.22	144	8,657
Oregon	40,497	13,583	13,453	.....	67,533	235,229	3.48	257	153
Pennsylvania, bituminous	108,600,585	2,985,188	3,202,352	35,733,401	150,521,526	153,029,510	1.02	233	175,403
Tennessee	6,255,707	132,750	117,365	615,558	7,121,380	7,925,350	1.11	225	11,930
Texas	1,843,356	20,702	28,118	.....	1,892,176	3,160,965	1.67	234	4,197
Utah	2,129,452	26,207	94,345	267,805	2,517,809	4,224,556	1.68	260	3,053
Virginia	4,063,382	88,284	147,621	2,208,710	6,507,997	5,877,486	.90	241	7,264
Washington	3,522,347	140,931	154,579	94,042	3,911,899	9,764,465	2.50	256	6,314
West Virginia	53,562,518	923,914	1,060,642	6,123,945	61,671,019	56,665,061	.92	228	68,663
Wyoming	7,160,332	88,548	284,208	.....	7,533,088	11,706,187	1.55	248	7,771
Total bituminous	342,969,220	12,286,851	9,667,621	52,187,450	417,111,142	469,281,719	1.12	217	555,533
Pennsylvania, anthracite	73,623,227	2,020,572	8,841,437	.....	84,485,236	160,275,302	1.90	229	169,497
Grand total	416,592,447	14,307,423	18,509,058	52,187,450	501,596,378	629,557,021	1.25	220	725,030

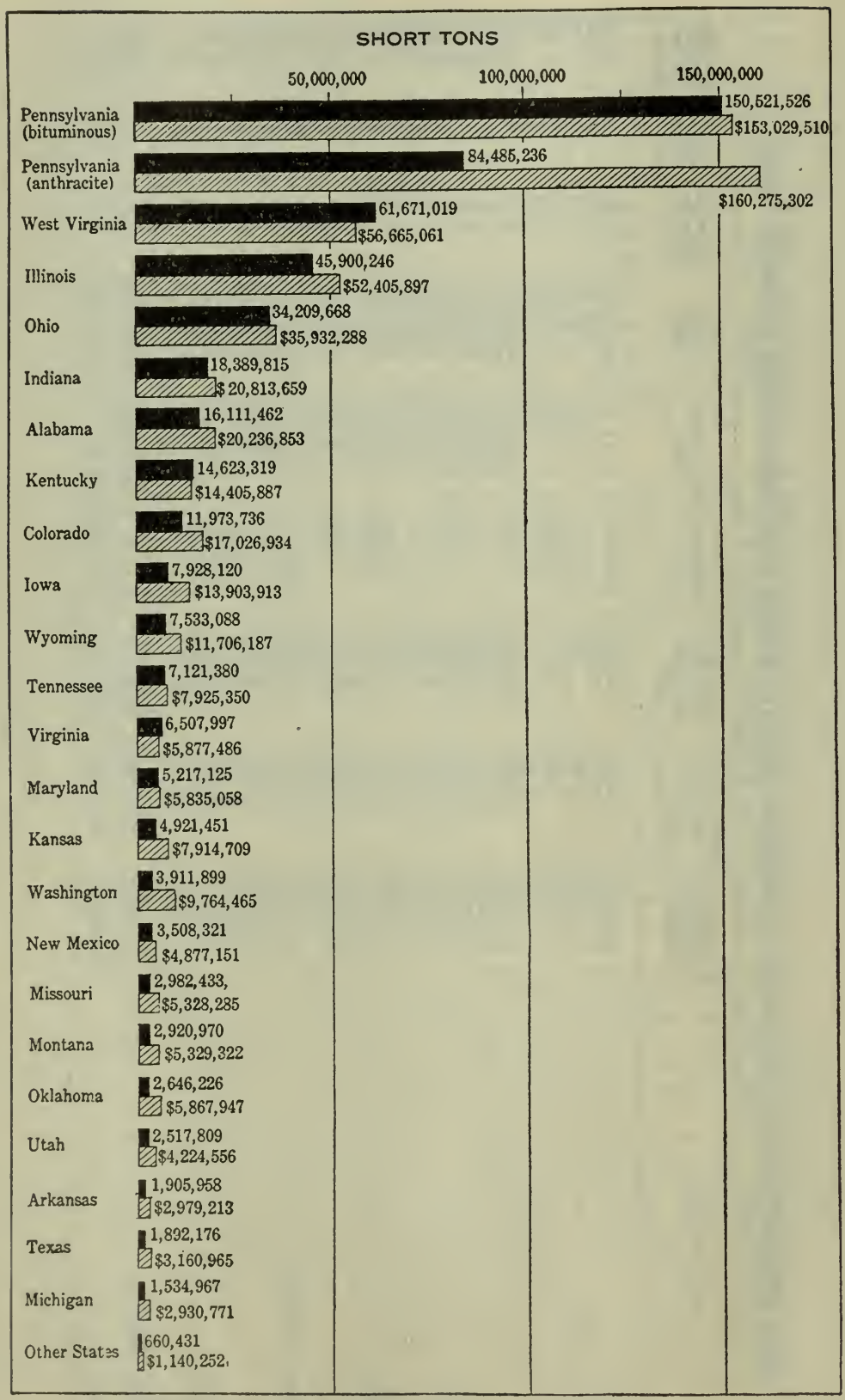


FIGURE 1.—Production of coal in the United States in 1910, by States.

*DURATION OF SUPPLY.

The total reserve of *easily accessible and now available* coal is estimated at 1,382,780,000,000 tons. The assumption that a constant output has been reached would be utterly unwarranted. On the other hand, the adoption of the flat rate of annual increase of 7.36 per cent. would involve the improbable assumption that the marvelous record of the past and present will be maintained in the future and the production would continue to approximately double every decade. Using the waste allowance, on the basis of this constant rate of increase in production, the 1,382,780,000,000 tons available at the close of 1907 would be exhausted in 107 years, or by 2015 A. D. Against the use of the flat rate of increase it may well be contended that, just as the rate of increase in population tends to diminish, so this rapid increase in per capita consumption of coal cannot persist, and a constant annual production will be reached. However, the figures set fifty years ago by statisticians for the probable constant annual production of coal in England have already been exceeded by over 160 per cent.

Mr. Henry Gannett has made an estimate based upon a decreasing rate of increase calculated from 20-year averages of production. The use of 10-year averages is regarded as unsatisfactory for the reason that one of the decades may consist mainly of a period of prosperity, while the preceding and succeeding decades contain periods of business depression. The 20-year period, however, is sufficiently long to include a period of prosperity with one of business depression. Taking the four 20-year periods since 1828, three rates of increase are obtained which show a rapid decrease. The hyperbolic curve computed from these successive rates of increase will indicate the constantly diminishing rate of increase for the successive 20-year periods. The result obtained by this method is that the easily accessible and available coal will be exhausted about the year 2027, and all coal by the middle of that century. It is recognized that the data upon which this curve has been constructed are few and the curve correspondingly weak. However, in the above estimate all of the data have been given which it is possible to use, and this estimate is believed to represent the best use that can be made of the data at hand.

Inasmuch as America leads the world not only in present production of coal, but also apparently possesses the greatest reserve and certainly is mining coal at much lower cost than any other country, the obvious tendency will be for European countries to look more and more to the United States for their coal supply. Therefore, while our present coal production and consumption are practically equivalent, the export of coal, unless prohibited by federal legislation, must eventually become a factor and increase the coal production in the United States beyond the demands of home consumption. On the other hand, powerful influences will come to bear upon coal production, which favor lengthening the life of the supply. Thus it is to be hoped that with more improved methods in the utilization of coal the increased efficiency per unit may act as a factor in reducing coal consumption, and improved mining methods should likewise decrease the waste percentage. The increased utilization of water power should also tend to decrease coal consumption. Again, as soon as the end appears in sight, prices will rise and production diminish, and that progressively. This interference with the law of decreasing increase produced by growing scarcity will, of course, prolong the life of our coal reserves, but at the same time will greatly hamper our industries that depend on this fuel.

With so many indeterminate factors whose importance is realized, but cannot be measured, prophecy must possess a questionable value.

*From Bulletin No. 394, United States Geological Survey.

WASTE IN COAL MINING.

The principal loss or waste attending coal-mining operations is that represented by the quantity of coal necessarily left in the ground as pillars to support the roof. In some cases it is also necessary to leave a foot or more of coal as a part of the roof, because of the unstable character of the material underlying the coal, which itself does not make a good roof. It has also been frequently the case that, where portions of the coal bed have been of inferior quality, only the high-grade coal has been mined and the poorer material left. The coal left as pillars, or as portions of the roof, may be considered a necessary loss, but that which is left because of its inferior quality cannot be considered unavoidable waste in any sense, and is frequently of higher grade than coals mined and used in other portions of the country.

Enormous quantities of coal have been lost beyond recovery from the mining of beds lying below, the caving of which, upon the withdrawal of the pillars, has so broken up the overlying strata as to render it impossible to recover the coals contained therein. This has been particularly the case in some of the coal beds of western Pennsylvania, but much improvement has been observed in this regard within later years. Notwithstanding the improvement in this respect it is probable that a large amount of coal will be wasted in the western states, where a great number of coal beds are closely associated, and also where the intercalated strata are weak, forming poor roofs to the mines.

There are no exact figures as to the actual loss or waste sustained through coal left in the mines in conducting the mining operations, but it has been estimated that it amounts to 50 per cent. of the quantity produced and marketed. In some cases, through careful mining and where the conditions are ideal for working, practically all of the contents of the coal beds are recovered. In other cases, particularly when the beds are of enormous thickness, the recovery has not exceeded 30 per cent. of the contents. During the earlier days of mining in the anthracite regions of Pennsylvania it was estimated that only 40 per cent. of the coal was marketed. This was partly due to uneconomical methods of mining, and partly to the large amount of culm, for which there was at that time no market and which was piled on the ground in unsightly mountains. At the time of the Anthracite Coal Waste Commission, which made its report in 1893, 40 per cent. was still considered a maximum recovery. So far as underground workings are concerned, there has been no revolution in the methods employed since that time, but there has been a considerable improvement in the application of those methods, which has resulted in the recovery at the present time of a materially larger proportion of the coal in the ground than was the rule at that date. The earlier methods of mining consisted in leaving comparatively narrow pillars, and in the mining of large rooms the result was that the pillars were not strong enough to stand the pressure and were crushed beyond recovery. It is now customary to use larger pillars between the rooms, which makes it possible to better control the roof during "robbing" operations and to eventually recover a larger proportion of the contents of the bed.

Material improvements have also been made in the methods of the preparation of coal, so that a much greater proportion of the product hoisted is now being sent to market in merchantable condition. Part of this is due to better and more systematic methods of handling, and part to the saving of small sizes which formerly went to the culm banks. The higher prices of coal and the development of methods for using these small sizes have also made it possible, through washing processes, to rework the small coal formerly thrown on the culm banks, and these are now furnishing several millions of tons of marketable coal annually.

CANADA.

TREE PLANTING AND REFORESTATION.

The Forestry Branch of the Department of the Interior (Government of Canada) has, since 1900, been carrying out a scheme of free tree distribution to farmers in the prairie provinces of Manitoba, Saskatchewan and Alberta. During that time some eighteen million trees have been sent out from the nurseries of this particular branch. The trees are planted on the homesteads throughout these provinces for windbreaks, shelter belts and wood supply. Nurseries have been established also on some of the forest reserves, and some planting is being done.

In 1894, the Government of the Province of Ontario established a nursery at the Ontario Agricultural College, Guelph, Ont., and they have since been distributing trees to farmers throughout that province. This nursery has since been removed to St. Williams, Ont., where the Provincial Department of Agriculture has acquired some 1,300 acres of sandy land, which it is planting up with forest trees. The Province of Quebec has also established a forest nursery at Berthier, P. Q., but the distribution from there has, as yet, been small. In a few instances, planting or sowing has been undertaken in other provinces of the Dominion by individuals or private concerns.

The Canadian Pacific Railway Company has also taken in hand the planting of trees of different varieties on the prairies. The trees and shrubs used are Russian Poplar and Willows, Box Elder, Ash, Spruce, Scotch Pine, Caragana and Artemosia. A good deal of this work is done along the cuts, in order that the trees and shrubs may serve as permanent snow fences.

There is also a permanent plantation at Wolseley, Sask., to determine the values of different species of trees for tie purposes, as well as for the correct spacing and mixture. The species selected are native tamarack, Scotch, red and jack pine, and although the plantation has not been established long enough to give any reliable figures as to growth, the results so far have been satisfactory. This plantation is situated on dry upland prairie. The tamaracks, or larch, used were transferred from swamp land to the plantation, and the growth on the high land, so far, has been three times faster than at any time in the swamp. It is hoped that this plantation will ultimately afford reliable information as to the selecting and planting of such trees as will eventually be suitable for tie timber.

Investigations are also being made by the Canadian Pacific Railway Company as to the value of cut-over and virgin timber lands in selected locations, in order to determine the value of these lands for permanent tie reserves. The information obtained from this source is not, as yet, sufficient to give out anything of a definite nature, but it will be continued, and in a few years it is also hoped that reliable information will be obtained regarding this reforestation.

The consumption of timber in the year 1910 was as follows:

Lumber	4,901,649,000 ft. B. M.
Square timber	37,962 tons
Shingles	1,976,400,000
Lath	851,953,000
Pulpwood	598,487 cords
Poles	782,841
Cross-ties	9,213,962
Mining timber (round)	52,848,000 linear ft.
Mining timber (sawn)	22,305,000 ft. B. M.
Cooperage (slack), including staves, heading and hoops	161,641,000 pieces
Cooperage (tight)	8,370,000 pieces

ANNUAL FIRE LOSS.

The information in regard to the annual fire loss is not definite, as much of the loss occurs in districts so far removed from settlement that it is impossible to make any reliable estimate. The annual loss from forest fires will, however, run between 250,000,000 and 500,000,000 ft., board measure, per annum. In very wet years it might fall below the minimum—in very dry years it will go over it. The value of the timber destroyed might be taken at one dollar per thousand at the stump. In the districts where railways are being constructed, they are the most frequent cause of fire—at least 50 per cent. of the fires bing caused by them. In the districts beyond where the railways are constructed, fires are mostly due to the clearing of the land by settlers.

COAL AND FUEL OIL RESOURCES.

In the Dominion the aggregate area of coal lands is 29,957 square miles, containing about 172,100,000,000 tons of the several classes.

Little, as yet, has been done towards ascertaining the loss incident upon coal mining operations in Canada. Nova Scotia has recently taken steps to secure this information by issuing coal depletion statement forms to be filled in by the mine operators. It has been stated by some authorities that for every ton of coal mined, one-half a ton is lost or wasted; and in thick beds the recovery probably does not exceed 30 per cent.

The wastes attending coal mining operations may be enumerated as follows:

(1) Coal lost beyond recovery by mining lowest seams first.
(2) Coal left in pillars to support the roof.
(3) The low grade coal left in the mines.
(4) Slack coal formed during mining operations.

In Western Canada where there are so many seams of great thickness close together, it is looked upon as important that the upper seams should be mined first, so that any caving as a result of removing the pillars will not render it impossible to get at the other seams.

Great losses have resulted also from improperly burned coal. The loss in smoke alone with bituminous coal has been estimated at about 10 per cent.

PEAT DEPOSITS IN CANADA.

In round numbers there are 37,000 square miles of peat lands scattered throughout the various provinces.

As a result of investigations carried on in Canada it has been demonstrated that:

(1) For the economic production of fuel from peat, machinery driven by power must be substituted as far as possible for manual labor.

(2) That processes so far invented for removing the water content of the peat by pressure or artificial heat have not hitherto led to profitable commercial results.

A number of bogs, however, are being exploited to some extent, and the result of the operation of one of them in particular, viz., the plant at Alfred, Ont., goes to prove that the production of excellent peat fuel is a commercial possibility.

It has been found that one ton of peat burned under boilers is equal to about 5/9 of a ton of coal. It does not clinker, nor give off any objectionable volatile matter in the form of black smoke, and as a domestic fuel, it is clean, easily handled and efficient.

CRUDE PETROLEUM.

The waste which occurs in oil production in Canada is not so much in the oil itself as in the natural gas incident to the oil production. The oil when obtained, may be sold at once, whereas to sell the gas, long expensive pipe lines must be laid, franchises obtained from towns or cities and their market is but limited.

NATURAL GAS IN CANADA.

The production of natural gas in Canada has increased in value nearly ten-fold during the last eighteen years, and of the total amount the Province of Ontario produced about 95 per cent.

Steps were taken by the Ontario Government in 1907 to prevent the waste of natural gas, and a law was passed levying a tax of two cents per 1,000 ft. with a rebate of 90 per cent. when the gas is used in Canada. This provision has been very effective.

In Alberta little provision has as yet been made for the plugging of the gas wells, and many millions of cubic feet have therefore been wasted annually and extended areas have been more or less drained.

In order to conserve the supply of natural gas, the gas must be utilized (1) for the purpose for which it is most valuable; (2) in the manner that will secure the greatest efficiency; and (3) as near as possible to the point of production. The most valuable uses for natural gas are for domestic purposes and the development of power.

REPORT OF COMMITTEE VIII—ON MASONRY.

G. H. TINKER, *Chairman;*
G. J. BELL.
H. E. BOARDMAN.
C. W. BOYNTON.
T. L. CONDRON.
L. D. CREAR.
L. N. EDWARDS.
A. H. GRIFFITH.
L. J. HOTCHKISS.
RICHARD L. HUMPHREY.
F. L. THOMPSON, *Vice-Chairman;*
W. H. PETERSEN.
PHILIP PETRI.
J. H. PRIOR.
F. E. SCHALL.
G. H. SCRIBNER, JR.
A. N. TALBOT.
JOB TUTHILL.
A. A. WIRTH.
Committee.

To the Members of the American Railway Engineering Association:

Your Committee on Masonry has held meetings as follows: At Chicago, on July 12, September 1, November 4, 1911, and January 20, 1912.

The various subjects assigned to the Committee for report were assigned to Sub-Committees for investigation.

REVISION OF THE MANUAL.

The Committee recommends no changes in the Manual at this time.

WATERPROOFING OF MASONRY.

In accordance with instructions from the Board of Direction, the investigation of the waterproofing of masonry has been continued during the past year. A circular letter requesting information relative to this subject was sent to the members of the Association. The circular letter followed, in the main points, the circulars issued in former years, adding such additional questions as appeared to your Committee called for in the light of present day practice.

The replies were quite numerous, but only a limited number contained information on the subject under consideration.

Abstracts from the replies containing information pertinent to the subject are appended; a perusal of these brings out the fact that while considerable waterproofing is being done throughout the country, the methods followed and materials used are much the same as described in previous reports of the Committee.

From several replies it will be seen that impervious concrete can be

made without special waterproofing, by using a suitable gradation of aggregates and the proper amount of cement and reinforcing the concrete to counteract temperature and shrinkage stresses, and in depositing to use the proper care and amount of work to secure a dense concrete.

It will also be noticed that in using waterproofing material such as felt, in connection with coal-tar pitch or asphaltum, fair results are obtained, when the weather conditions are favorable, and when the work can be done without interference or obstructions and by working continuously until completed; it is also noticed that when the work is done at an unfavorable season, or when work is done in distinct separate periods and sections, under difficulties such as track operations, undue haste in completing the work necessitated by special circumstances, the results have generally been unsatisfactory.

The Committee has not prepared a final report on the subject of waterproofing; the appended abstracts are submitted as information.

ILLINOIS CENTRAL RAILROAD COMPANY.

Waterproofing double-track steel viaduct, through girders with I-beam floor encased in concrete. Deck girder approaches with concrete floor. Waterproofing to protect steel, no head. Waterproofing consisted of three layers of felt, one layer of burlap, two layers of felt, a mopping of pitch on the concrete, between each layer of felt and burlap and over all. The work was completed in 1908 and is satisfactory and no leak on last inspection in October, 1911. The waterproofing was protected by a layer of fine crushed stone and screenings embedded in and covered with pitch. Expansion was provided in concrete, but no provision for expansion was made in the waterproofing. The cost of the waterproofing, including the protection, was 15 cents per sq. ft.

CENTRAL RAILROAD COMPANY OF NEW JERSEY.

Mr. Jos. O. Osgood, Chief Engineer. Supplemental answers given to Circular 122, November 16, 1909.

Bridge No. 29¾, Central Division: No leaks when last inspected in May, 1911.

Bridge No. 60½, Central Division: No leaks when last inspected in October, 1911.

Bridge No. 42, N. J. S. Division: No leaks when last inspected in May, 1911.

Bridge No. 34, Central Division: Leaks appeared along the webs of main girders during last winter. These were caused by throwing the snow during the flanging of the tracks along the webs of the girders. When a thaw set in, the melting snow was held in a pocket in such a manner as to bring the water above the flashing angle and back of the waterproofing. This difficulty has been remedied in our later bridges by placing the flashing angle and carrying the waterproofing at least a foot above the top of rail. In this bridge the waterproofing was stopped about on a level with the base of rail.

The cost of forty cents per sq. ft. includes the furnishing and applying of waterproofing materials and the cost of the protecting brick in place. The cost of the brick was $8.00 per thousand, f. o. b cars at the work.

Bridge No. 63, Central Division, and 13 other bridges: Leaks appeared along the webs of the girders from the same cause as stated under Bridge No. 34.

Bridge No. 4½, Manufacturers' Branch: No leaks when last inspected in May, 1911, except as stated in former report.

Bridge No. 136, Central Division, Hampton, N. J.: Waterproofed November, 1910, with four layers of Barrett's Specification Felt and one intermediate layer of Barrett's Tartex, cemented together with Barrett's Specification Pitch, waterproofing carried to the under side of flange angles of main girders. The cost of waterproofing this bridge, including the brick protection, was $0.273 per sq. ft.

No leaks have appeared up to the last inspection of May, 1911.

Bridge No. 19, Central Division: Completed September, 1911. Waterproofed with four layers of Barrett's Specification Felt and an intermediate layer of Barrett's Tartex, cemented together with Barrett's Specification Pitch. Protected by brick laid flat with joints poured with pitch. The cost per sq. ft., including brick protection, was $0.123 for materials and $0.066 for labor. The brick cost $8.00 per thousand, f. o. b. cars at the work.

Bridge No. 218, Central Division: A double-track, half-through plate girder structure about 45 ft. long, with I-beam floor encased in concrete. Completed November, 1910.

For waterproofing the upper surface of the concrete was given two coats of Hydrex Waterproofing Paint. As soon as the painting was completed the ballast was placed immediately on top with no protection for the waterproofing. Up to the last inspection of May, 1911, no leaks had appeared.

The concrete at the main girders was carried up to the flange angles of the girders which were about 20 in. above the top of rail. The painting was also carried to that point.

The general practice of this company is still the same as outlined in the concluding paragraphs of my letter of November 16, 1909, above referred to.

PENNSYLVANIA LINES WEST OF PITTSBURG.

Mr. R. Trimble, Chief Engineer Maintenance of Way, states that the reply to Circular 122 in 1909 and 1910 contain all the information they have on the subject.

The latest examinations made show the conditions to be the same as previously reported.

NEW YORK CENTRAL & HUDSON RIVER R. R. CO.

Mr. George W. Kittredge, Chief Engineer, furnishes the following information:

GENERAL REMARKS: Trouble experienced in the case of felt and coal-tar pitch is mostly on account of the poor class of labor used. It does not prevent leakage when the body walls are not built continuously. Trouble is also caused by lack of care in joining successive sections of work, horizontally or vertically.

SUBWAY AT PASSENGER STATION—BUFFALO.

The subway leading from the Buffalo Passenger Station is of rectangular section, 20 ft. in width and 7 ft. in height inside, serving 12 tracks. The side walls are of monolithic construction similar to ordinary retaining walls, and the floor is extra thick of the same construction. The roof is of 20-in. I-beams, with concrete filling between, covered with three inches of cement, with waterproofing and with a protection of brick on top of this and under the ballast. The entire outside of walls was covered with waterproofing consisting of 6-ply tarred felt, each layer put on separately, with Sarco compound, and outside of this the side walls and the top are protected with brick laid in cement. The floor is protected by 6-in. layer of concrete under the waterproofing, the floor itself above the waterproofing being 10 in. thick, the extra weight being given to prevent float-

N. Y. C. & H. R. R. R. CO.

INFORMATION CONCERNING APPLICATION OF WATERPROOFING—1902-1911

Location	Character of the Structure Waterproofed	Conditions Requiring Water-Proofing Head of Water, if any	Materials Used	Date Applied / Date Examined	Remarks
Albany.....	Subway under tracks at passenger station.	Surface water	¾-in. asphalt	Ap. 1902 Ex. 1910	Satisfactory as to walls; roof leaked badly; copper subroof put in to take care of moisture.
Brewster.....	Coaling station pit..	6-ft. head.....	6-ply tar and Felt	Ap. 1910 Ex. 1910	Leaked badly; repaired by Hydrolithic compound applied by the Hydrolithic company
Buffalo.....	Scajacuada Creek arch, 40-ft. span	Surface water only	¼-in. coal tar pitch	Ap. 1908 Ex. 1910	Good; the only leaks showing were in vertical joints
Buffalo.....	Belt Line reinforced concrete arch	Surface water only	Tarred felt coal tar pitch, ¼-in. cement mortar	Ap. 1908 Ex. 1910	Satisfactory
Buffalo.....	Belt Line reinforced concrete arch	Surface water only	¼-in. coating straight run coal tar pitch	Ap. 1908 Ex. 1910	Satisfactory
Cohoes.....	Reinforced concrete arch, Columbia Street	Surface water only	½-in. plaster of 1:2 cement over 1 layer of tarred felt over ⅛-in. of straight run coal tar pitch	Ap. 1909 Ex. 1910	Satisfactory
Onchiota.....	Concrete arch, 20-ft.	Road bed surface Drainage	⅛-in. coal tar pitch over 1-in of 1:2 Portland cement mortar	Ap. 1906 Ex. 1910	Satisfactory
Poughkeepsie.	Back of retaining walls	For surface drainage	⅛-in. coal tar pitch	Ap. 1908 Ex. 1910	Fairly satisfactory
Poughkeepsie.	Back of retaining walls	For surface drainage	Medusa compound	Ap. 1908 Ex. 1910	Water stained; walls nearly always let water through at horizontal joints where work ends one day and begins next
Rippleton....	40-ft. concrete arch..	Surface drainage	⅛-in. coal tar	Ap. 1906 Ex. 1910	Very little value; leaks through intrados every 3 or 4 feet
Troy.....	Subway.....	4-ft. head.....	¾-in. asphalt protected by brick	Ap. 1902 Ex. 1910	Very satisfactory
Miscellaneous	Retaining walls.....	Ground and surface water behind walls	⅛-in. coal tar pitch	Ap. 1900 Ex. 1910	Leakage found usually at horizontal and vertical joints where work was discontinued

age, and prevent its being cracked by the upward pressure of the water. Waterproofing of sides and floor was made continuous as far as possible.

The conditions requiring waterproofing were as follows: This construction is in a bed of clay which extends about half way up the height of the subway, the remaining 6 ft. or so is of a loose gravel, so that all of the surface water coming through the porous matter is held by the clay under slight head.

The construction of this work was carried on under considerable difficulty, it being necessary to work while the traffic, which is very heavy at this point, was going on, and it was possible to build only a part of the subway at a time, and not make a continuous job of it. It is probable that at points where one piece of work left off, and another began, the connection between the waterproofing was imperfect, as cracks began to develop, and the water came into the subway in small quantities in numerous places almost as soon as completed. This was remedied by careful application of ½-in. hydrolithic cement by the Waterproofing Company, on the inside of the subway, so that the structure is now tight, except the roof, where on account of the vibration of the trains, it was practically impossible to insure an absolutely tight job. Great care was taken to find all cracks and dig them out, and fill them with hydrolithic cement. The cost of the hydrolithic waterproofing was about 30 cents per sq. ft., and has now been on for two years, and has given good satisfaction.

Referring to letter of September 16, 1911, in the matter of waterproofing of masonry: I sent on February 10 last considerable information on this subject and at this time can only add a few remarks in regard to waterproofing which we found on the old Park Avenue tunnel roof where a portion of it was removed at 59th Street.

The roof consisted of iron beams with brick arches which were leveled up with concrete. The waterproofing was placed directly on this concrete and was covered with about two ft. of earth which formed the soil for the parking around the openings in the roof of the tunnel. Drains were provided so that the water did not stand in the earth. The materials were of felt and coal-tar pitch, three plies of felt being used. We have no information as to the method of application or the cost of the work. I have understood indirectly that this waterproofing was placed when the tunnel was built, some forty years ago. From recollection of the tunnel for the past ten years the vegetation over this waterproofing was in such a state that the waterproofing must be at least twenty years old. The waterproofing was removed on account of changes we were making last winter, and it was in fair condition. The paper had become somewhat brittle, also the pitch was harder than pitches we apply now, but the sheet of waterproofing was intact and capable of shedding water. Small leaks would not have been detected; the only protection of the concrete was the soil placed over it. The waterproofing covered the tunnel roof from 58th to 59th Street, and presumably extends a good deal farther. There was no provision for expansion joints.

MICHIGAN CENTRAL RAILROAD.

(A) Fifteenth Street Bridge, 3 spans, through plate girders, I-beam plate ballast floor; masonry abutments.

(B) Twenty-fourth Street Bridge, 3 spans, I-beam plate ballast floor on steel bents; masonry abutments.

(C) Vinewood Avenue Bridge, 3 spans, I-beam plate ballast floor bridge on steel bents and masonry abutments.

(D) Scotten Avenue Bridge, same as Vinewood Avenue.

(E) Clark Avenue Bridge, same as Vinewood Avenue.

(F) Twenty-third Street Bridge, same as Vinewood Avenue.

(G) Sixteenth Street Bridge, same as Fifteenth Street.

(H) Fourteenth Street Bridge, same as Fifteenth Street.

(I) Beaubien Street Bridge Peninsular Spur, same as Fifteenth Street.

(J) Brush Street Bridge Peninsular Spur, same as Fifteenth Street.

(K) Beaubien Street Bridge, 3 spans, built up beams on concrete bents and concrete abutments. Beams embedded in concrete.

(L) Brush Street Bridge, 3 spans, Bethlehem beams on concrete bents and abutments. Beams embedded in concrete.

(M) John R. Street Bridge, same as Brush Street.

(N) Tecumseh Road, one 75 ft. through girder span with I-beam floor and concrete slab on top of I-beams.

(O) Beecher Avenue Bridge, 3 spans, built up beams with plate, ballast floor, on steel bents and concrete abutments.

(P) Twentieth Street Bridge, same as Beecher Avenue.

(R) Military Avenue Bridge, same as Beecher Avenue.

(S) Livernois Avenue Bridge, same as Beecher Avenue.

All the structures mentioned above required waterproofing to keep floor dry over the streets as follows:

For (A), (B), (C), (D) and (E): Mop coat of Sarco with 1½ in. sand and Sarco mastic and pouring coat of No. 6 Sarco on top of mastic.

For (F): Mop coat of Sarco, 1½ in. sand and pitch mastic to cover rivet heads, on top of this 5-ply Barrett Felt and pitch protected by 1½ in. pitch Torpedo gravel mastic.

For (G): Mop coat of Sarco, 1½ in. sand and Sarco mastic to cover rivet heads, 2-ply Barrett Felt mopped with Sarco No. 6, 1½ in sand and Sarco mastic. Pouring coat of Sarco.

For (H): Mop coat of Sarco, 1 in. coat of sand and Barrett pitch to cover rivet heads, 5-ply Barrett Felt mopped with pitch, 1½ in. of Torpedo gravel pitch mastic with pouring coat of Barrett pitch.

For (I), (J), (K), (L) and (M): Paint with Sarco Primer, 3-ply, 8 oz. Burlap mopped with Sarco No. 6, 1½ in. Sarco mastic, pouring coat of Sarco No. 6.

For (N): Paint coat of Sarco Primer, 3-ply, 8 oz. Burlap mopped with hot Sarco No. 6, 1½ in. protection coat of Sarco mastic and Torpedo gravel.

For (O) and (P): One and one-half in. Sarco sand and mastic, 3-ply, 8 oz. Burlap mopped with No. 6 Sarco; 1½ in. Sarco Torpedo gravel mastic and pouring coat of hot mastic.

For (R) and (S): One and one-half in. sand pitch mastic, two layers of felt mopped with Barrett Pitch and one layer of reinforcing felt mopped with Barrett Pitch; 1 in. Barrett sand and pitch protection coat.

COST PER SQUARE FOOT OF SURFACE COVERED.

	Labor	Material	Total	Completed
(A)	3-9/10	5-5/10	9-4/10	August, 1908
(B)	2-9/10	6-4/10	9-3/10	June, 1909
(C)	2-7/10	6-9/10	9-6/10	September, 1908
(D)	2-5/10	7-2/10	9-7/10	June, 1908
(E)	3-2/10	7-8/10	11	June, 1908
(F)	7	7-4/10	14-4/10	June, 1909
(G)	4-7/10	9-7/10	14-4/10	August, 1908
(H)	7-5/10	6-8/10	14-3/10	July, 1908
(I)	20	16-4/10	36-4/10	Done in winter; trouble with snow and ice. December, 1910
(J)	9-3/10	16-9/10	36-2/10	December, 1910
(K)	6-4/10	14-4/10	20-8/10	December, 1910
(L)	9-5/10	15-5/10	25	March, 1911
(M)	8-5/10	17-1/10	25-6/10	January, 1911
(N)	10	8-6/10	18-6/10	June, 1910

	Labor	Material	Total	Completed
(O)	7-3/10	18-8/10	26-1/10	November, 1910
(P)	7-2/10	16-2/10	23-4/10	July, 1910
(R)	4-6/10	10-	14-6/10	May, 1910
(S)	5-8/10	10-8/10	15-6/10	May, 1910

(A) Leaks badly over posts at gusset plate connections and small leaks at nearly all beam connections in northbound track. Leaks at 25 per cent. of beam connections in southbound track.

(B), (C), (D), (E) and (F). No leaks.

(G) Leaks over posts at gusset plate connections only.

(H) Leaks over posts at gusset plate connections only.

(I), (J), (K), (L) and (N). No leaks.

(O) Two small leaks over supporting girder, third panel from north end.

(P), (R) and (S) No leaks.

EL PASO & SOUTHWESTERN SYSTEM.

Have waterproofed in 1908 about 194,000 sq. ft of concrete lined reservoirs, using the Sylvester process of soap and alum, two coats of each, and by painting surface with asphalt and Elaterite waterproofing. We depended largely upon this waterproofing for water-tightness, and the concrete was not as rich in cement as it otherwise would have been. Theoretically the mixture was 1:2:4; actually, some of it was not quite as rich. We had considerable trouble with leakage through portions of the concrete and, upon examination, such parts were generally found to be evidently porous.

After a period of three years, we find the asphalt and Elaterite coating to be a pronounced failure on account of peeling off in the winter time through action of frost. We find the Sylvester process of soap and alum quite efficient. Except in places where the concrete is evidently quite inferior, the soap and alum has made the concrete watertight. Where the concrete was good and the work thoroughly done, the water will stand and roll on the surface of the concrete as it will on plate glass. Of course, the concrete is not actually as impervious as the glass, but drops of water on the concrete so waterproofed disappear by evaporation rather than by absorption.

The sand and gravel used in lining these reservoirs were of a fair grade only, the maximum size of gravel being 1½ in. The concrete lining was from 4 to 6 in. thick. The gravel was not as finely graded as it should have been and the larger stones were evidently too large for that kind of work.

The cost of waterproofing with soap and alum was 43/100 cents per sq. ft.; with asphaltum 1 4/10 cents and with Elaterite waterproofing made by the Elaterite Paint Mfg. Co., Des Moines, 1½ cents per sq. ft. (For former report on this, see Proceedings, Vol. 12, Part 1. page 513.)

A few months ago we completed a reinforced concrete septic tank 30 ft. in diameter and 12 ft. high, with shell 6 in. thick. No waterproofing was used in this concrete. The latter was theoretically a 1:2:4 mix, but we actually used a somewhat greater percentage of cement. The sand and gravel were good. The specifications for the gravel required it all to pass through a ½-in. screen. This tank is entirely watertight except at the joints between successive courses of concrete. It appears to be demonstrative of the possibility of making concrete watertight, at least for the light pressure existing in this particular tank.

First-class sand and stone, carefully graded, to reduce the voids, and a liberal margin of cement in excess of the voids in the sand and stone, and thorough uniformity in the mixing and laying are, we believe, more efficient than anything else in making concrete waterproof. The maximum size of the stone should not exceed ¾-in. and we think that ½-in. is better.

CHICAGO, BURLINGTON & QUINCY RAILROAD.

In 1909 or 1910 we furnished the Committee with some discussion on the subject of waterproofing. We have some of this waterproofing in service for about three years, and where it was properly put on, it is in good shape.

It will be noted at the right hand end of the blueprint enclosed the old method is shown. Here the waterproofing passes down over a steep slope. In some cases the pressure from the ties has forced it down the slope, tearing it apart. In order to avoid this trouble, the new method shown at the left hand end of the blueprint was adopted. The slope was made flat and the burlap was laid over a long piece of gas-pipe, placed at the top of the slope and withdrawn as the work proceeded, leaving something in the way of an expansion joint.

This has been quite successful, but if we have more of this kind of work to do, we shall make the subway slabs the same thickness as the roadway slabs, thus getting a uniform slope from the center of the street to the back of the abutment.

We are now engaged in repairing some of this waterproofing where leaks have occurred. The work was done in frosty weather and we find that the first ply of burlap was not saturated at all; the second ply begins to be saturated; the third one a little more and the fourth and fifth ones are well saturated.

On all of this cold weather work so far examined, the mastic protection over the burlap is cracked badly and the burlap at the bottom of these cracks has rotted. For purposes of comparison with this work, we have cut out a few pieces of waterproofing from portions of the structure put in the same year, but where the work was done in warm weather; here the waterproofing is in perfect condition. We attribute the cause of the trouble entirely to the fact that the waterproofing was laid in cold weather when the concrete surface upon which it was laid was cold, and the asphalt chilled before it had an opportunity to saturate the burlap.

The original cost of this work was 13-3/10 cents per sq. ft.. 9-3/10 cents being for material and 4 cents for labor. (For former information, see Proceedings, Vol. 11, Part 2, pp. 991-992.)

NORFOLK & WESTERN RAILWAY.

Subway for use of passengers under tracks at Petersburg, Va. Constructed of concrete, a 6-in. layer of concrete is placed on the area of foundation, upon this concrete against the outer forms 4-in. brick walls are built, and on the concrete base and against the brick walls the waterproofing, consisting of a coat of Sarco concrete primer applied hot, a heavy swabbing of Sarco No. 6 waterproofing and 3-ply membrane No. 16 Sarco Asphalt felt; the felt is lapped so that there is at no point less than three thicknesses of felt, each thickness being heavily swabbed with hot Sarco No. 6 waterproofing before succeeding thickness is applied.

The membrane is well swabbed with Sarco No. 6 and while this coat is still hot a layer of 8 oz. burlap is applied, this layer is also swabbed with No. 6 Sarco and a second layer of 8 oz. burlap, breaking joints with the first, is laid.

The last layer of burlap when dry is swabbed with hot Sarco.

The concrete walls, floor and steps of the subway are then built against the waterproofing above described.

The concrete subway roof reinforced with steel rails and expanded metal, laid with a crown of 1 in. for drainage is waterproofed by a mat of 2-ply burlap and 3-ply felt laid as described for sidewalls, except that the burlap is laid first or on the bottom of the mat. The roof waterproofing is protected from cutting by the ballast by a layer of 1¼ in. of Sarco Asphalt Mastic applied in two coats of ⅝-in. each, with lapped joints.

This work was done about a year ago and has proven satisfactory. Cost of waterproofing complete about 50 cents per sq. ft.

CHICAGO CITY RAILWAY COMPANY.

Car Houses and Car Repair Shops. Advise that the old roofs are about the same as they were a year after completion; no new leaks have developed since that time. (See Proceedings, Vol. 11, Part 2. page 971.)

Particular attention is called to the design of roof over the addition to the Thirty-eighth and Cottage Grove car house, constructed a year and a half ago and to this date shows no sign of a leak. No waterproofing was used, water tightness was obtained by dense concrete reinforced to resist shrinkage and temperature stresses. The body of the roof slab was mixed in 1:2:4 with ¾-in. top finish cement and sand 1:3 mix. On this structure, expansion joints were used. Size of stone specified was to pass a ¾-in. ring and under. The concrete was mixed very wet.

INDIANAPOLIS WATER COMPANY.

Mr. William Curtis Makee calls attention to the Clear Water Reservoir at Riverside Pumping Station, Indianapolis, 257 ft. by 377 ft. with walls 10 ft. high, floor, walls and roof built monolithic; built in 1907 and examined in 1911 and showing no leaks. The cover is flat and supports two feet of soil, drainage being carried off by means of open jointed drain pipes laid on the cover. No waterproofing was used.

Concrete was of dense construction reinforced with steel bars for shrinkage and temperature stresses. Proportions 1 cement to 6 unscreened bank gravel; head of water contained 8 ft.

Also calls attention to three filter covers each 200 by 350 ft. joined at the center for a length of 350 ft. to a partition wall 14 ft. high. The covers are laid on a slope of 5/10 per cent. and required to shed storm water; 2 ft. depth of screened cinders are placed on the covers. No leaks, except slight seepage at junction of entrance to flat slab.

The work was completed in 1906 and last examination in 1911 shows the results above noted. No regular expansion joints were used; the entire roof slides on supporting walls on paraffin joint. The mixture was 1 cement, 2 parts of sand and 4 parts of stone mixed very wet. The water pressure was 10-ft. head on dividing walls. There are some leaks in dividing walls due to the aggregate stratifying; the leaks being in horizontal seams and quite small.

PHILADELPHIA & READING RAILWAY.

(Waterproofing of Masonry, P. G. & N. Elevated.)

Refers to report of November 1, 1909, on the same subject with supplement as published in Proceedings, Vol. 12, Part 1, page 510.

No noticeable difference in the number of leaks is apparent except perhaps that the total amount of leakage is not so great and those structures originally reported as water tight are still in the same condition. Last inspection was made in September, 1911.

In regard to new work, this is reported under three heads: (a) Bridge on Contract No. 11, P. G. & N. Elevated; (b) Waterproofing of steel Viaduct between Brown and Jefferson Streets; (c) Bridge over Master Street—all located in the City of Philadelphia.

(a) Consist of nine half-through plate girder four-track bridges. Total area of bridge floors, 56,500 sq. ft.

(b) Top of deck plate girder four track viaduct. Total area of waterproofing, 197,300 sq. ft.

(c) Deck plate girder span with buckle plate floor. Area, 3,050 sq. ft.

The protection of the steel work of bridges and of street underneath required the waterproofing and applies to all cases.

Materials used for (a) and (b) natural rock asphalt mastic 1½ in. thick applied in two coats and supported by 1:3:6 concrete filling in troughs of steel floor. And for (c) five layers Genasco felt protected with brick laid on concrete filling of buckle plate floor.

The cost for (a) is reported at 24 cents and 31 cents per sq. ft., for (b) 24 cents per sq. ft. and for (c) 26 cents per sq. ft. These costs include, in all cases, the concrete. Under (a) the troughs were 12 in. deep, and under (b) 6 in. deep.

Under (a) one-half of each bridge completed October, 1910; balance June, 1911; (b) one-half completed in December, 1910; balance May, 1911; (c) completed December, 1910.

Very few leaks have appeared under any of the nine bridges under (a) except in two places where the old work joined with the new on account of connecting the two sections. This joint has given trouble along one girder.

(b) Is generally tight except at expansion joints; these joints occur about every 150 ft., and are now being treated with a layer of pure asphalt with a high melting point and a low brittle point, placed over the joint. One-half of the viaduct has been so treated and proved very effective.

(a) and (b) No protection of waterproofing was used; ballast resting directly on the mastic. For (c) the waterproofing is protected with a layer of hard brick laid in waterproofing compound.

ST. LOUIS & SAN FRANCISCO RAILROAD.

Reports on reinforced concrete beam subway bridge—2 spans, 25 ft. and 12½ ft., supporting 3 tracks. Waterproofed by using 16 parts old process coal tar, 4 parts Portland cement, 1 part kerosene, applied hot by means of a brush. The tar was heated first and kerosene and cement added; 3 heavy coats used on top, 2 heavy coats on rear face of abutments.

Cost of labor $0.00519 and for materials $0.00418, or a total of $0.0092 per sq. ft. of surface treated.

Work was completed in October, 1910, and examined in October, 1911, and no leaks discovered. No protection to the waterproofing was used; 12-in. ballast ties on top of the reinforced slab and cinder filling was used against the abutments of each joint.

One expansion joint over supporting columns protected by raising concrete along each side of joint. The surface of the entire structure is small and sloped for drainage.

PITTSBURG & LAKE ERIE RAILROAD.

Reports waterproofing on five 40 to 50 ft. four-track half deck and through girder bridges. Floor stringers spaced 15 in. center to center. Space between floor stringers filled with concrete.

Waterproofed to protect the metal work and also against dripping to the street under bridge.

Waterproofing consisted of Sarco No. 6 waterproofing with 8 oz. open mesh burlap; 1¾ lbs. of 1:2 cement mortar protection over waterproofing.

On the clean dry surface of concrete floor was applied a coating of Sarco Concrete Primer thin enough to penetrate the recesses of the concrete. Primer in some cases being too heavy was thinned with gasoline. After the primer dried (requiring about one hour) a heavy coating of hot Sarco No. 6 Waterproofing was applied and while the material was still hot a layer of 8 oz. open mesh burlap was laid.

To apply the burlap on the hot Sarco, first have it rolled on a 2-in. round stick and start unrolling immediately after applying the Sarco, exercising care to keep it straight and free from folds. Follow closely the unrolling of burlap by brooming with a rattan broom. This method was followed until three layers of burlap was applied.

On top of the last layer of burlap a heavy coating of hot Sarco was applied. As soon as convenient, after the Sarco waterproofing was applied, a 1¾-in. thickness of 1:2 cement mortar was laid.

Cost of labor $0.026 per sq. ft. treated and $0.044 for material, making a total of $0.070 per sq. ft. treated for 3 bridges on which complete data were kept. Results obtained were reported in paragraph 7, Bulletin 130, Masonry Committee reports on "Waterproofing." Last examination made September 25, 1911.

For the Sharon Road Bridge and Lion Lane Bridge: No leaks in concrete roof apparent. A few rivets in the girders show that at some time water must have passed through waterproofing.

Leopard Lane Bridge: Under No. 1 track water is dropping slowly at three places. At six other places indications point that water has been dropping at some time and at a few other places in girders indications are that water has passed through rivet holes at some time.

Third Street Bridge: No. 1 track, no leaks. No. 2 track, five places at edges of floor-beams indicate that water has come through and at two of these places it was dropping slowly at last inspection. Track No. 3, two places water dropping. Track No. 4, no leaks.

Second Street Bridge: A good many leaks show at this bridge. This is the bridge on which an unfavorable report was made before and there is no indication of any decided change. Leaks show at edges of floor-beams and girders. Water is slowly dropping through at many of the rivets.

The reason advanced for the unfavorable condition of waterproofing on these bridges is that the concrete was not allowed to set up naturally, artificial heat having been applied to dry it preliminary to applying the Sarco Primer, and in some cases the waterproofing was applied in unfavorable weather conditions.

Have just completed bridge at Aliquippa, which was waterproofed in the same manner as those above described but with all conditions favorable for a fair test, such as dry concrete on which to apply the first coat (Primer) and dry and warm weather during the time the waterproofing was applied. It will be interesting to observe the results in connection with this structure which is known as the Third Street Subway at Aliquippa.

Another reason advanced for the failure of the waterproofing outlined in the first paragraph is that the cement mortar cover may be broken under impact of traffic and the ballast may have cut the waterproofing.

Third Street Subway, Aliquippa, Pa.: This is a ballast bridge, 288 ft. wide, and supporting about 20 tracks. The distance between abutments is 40 ft. and a line of columns supports the floor structure at the center.

The floor is made of 15-in. 80-lb. I-beams, 44 ft. long, spaced 15 in. c. to c. and filled between with 1:3:5 concrete.

The structure is waterproofed with Sarco No. 6 waterproofing, with 2-ply. of 8-oz. open mesh burlap, using same method given in answer to question No. 4 of Circular dated September 16, 1911, except that two layers of burlap were used.

The area covered was 14,000 sq. ft.

Sarco Primer, 151 gals. @ $0.35 per gal.	$ 52.85
Sarco No. 6, 16,200 lbs. @ $35.60 per ton	288.36
Burlap, 1,560 lbs. @ $0.08 per lb.	124.80
Total cost of material	$466.01
Total cost of labor	251.38
Total cost of labor and material	$717.39

Material cost $.033 per sq. ft.
Labor cost $.018 per sq. ft.
The waterproofing was protected by 1¾-in. cement covering made of 1:2 mortar. The area covered 13,320 sq. ft.

Sand used, 52 tons @ $0.65	$ 33.80
Cement, 131 bbls. @ $0.85	111.35
Labor	103.00
Total	$248.15

Material cost $.011 per sq. ft.
Labor cost $.008 per sq. ft.

The waterproofing was applied at different times between May and August, 1911, under favorable weather conditions and is in good condition at this date, October 5, 1911.

SANTA FE RAILWAY SYSTEM.

(Waterproofing of Scale Pits and Hopper Pits for Mechanical Coal Chutes.)

Pits were about 5 ft. deep and water level was within 1 ft. of surface. Three-ply Hydrex felt was used on one scale pit with poor results; used ironite, a paint, on one scale pit with fair results; used 8 per cent. hydrated lime mixed with dry cement on coal chute pits obtaining good results. The mix of the mortar was 1:1 and the concrete 1:1:2. No record was kept as to cost. The work was done three to five years ago and, when examined about six months ago, there were no leaks.

LONG ISLAND RAILROAD.

(Reinforcing Concrete Floors for Steel Bridges Carrying Railroad Tracks.)

Six layers of pitch, four of felt and one (the middle) reinforced by cloth, each layer thoroughly swabbed with hot pitch on the felt. The total cost per square foot of surface treated from 12 to 20 cents. The work was done from 1908 to date—10 bridges. First-class results were obtained and on last examination, October, 1911, there were no leaks. The waterproofing is protected by brick, the cost of which is included in the above figures. No expansion joints were used in any of the floors.

Have used, in the construction of a small concrete water tank at Long Island City, inside plaster with mortar mixed 1 cement, 1 sand and 2 gals. soft soap and about 2 qts. of granulated alum per barrel of cement.

The results obtained are not stated.

CANADIAN PACIFIC RAILWAY.

(Waterproofing Subways.)

McPhillips Street Subway: Deck of subway of steel plate. Waterproofing used dry felt, tarred felt, burlap and Gilsomite asphalt, applied as follows:

On the steel deck is laid a layer of dry felt, then a layer of tarred felt with asphaltum, over this is laid two layers of burlap each mopped with asphaltum, then a layer of tarred felt mopped with asphalt, over this is laid a layer of tarred felt not mopped and last a layer of dry felt. The cost of this waterproofing was 12½ cents per sq. ft. The work was completed in 1911 and at last inspection during October, 1911, was found satisfactory. Two small leaks appeared along joint made with previously constructed waterproofing. Waterproofing is protected by a coat of tar concrete 4 in. thick. The cost of this protection is 9 cents per sq. ft.; this is not included in the above price for waterproofing.

The work covers 10,500 sq. ft. Expansion is taken care of by the layers of dry felt.

Rachael Street Subway: Reinforced concrete deck waterproofed by burlap and pitch, using five layers of burlap and pitch between each layer. The work was completed in 1908 and is fairly satisfactory. On last examination in October, 1911, a few small leaks showed. No protection to waterproofing was used. The ballast was laid directly on top of the waterproofing.

Weston Shops (Winnipeg): Deck of subway, old rails encased in concrete. Waterproofing material, burlap and asphaltum.

The concrete was first covered with a layer of asphaltum on which is laid one thickness of burlap, then a layer of asphaltum, then another thickness of burlap and then a good covering of asphaltum over all. The total cost of this waterproofing is 8½ cents per sq. ft. The work was done in November, 1910, and results obtained are satisfactory; last examination in October, 1911, showed no leaks. No protection was used over the waterproofing. Gravel was laid directly on the waterproofing.

Union Station (Regina): Conditions requiring waterproofing; surface water and leakage from tank and pipes leading from dam to roundhouse, gardens and various buildings. Materials used were cement mortar and pitch. The waterproofing was applied as a plaster against the wall and afterwards given a good coating of pitch. The cost of the waterproofing labor was 1.93 cents; the cost of waterproofing material was 2.72 cents; total cost of waterproofing per square foot of surface treated was 4.88 cents, this includes superintendence. Work was completed in August, 1911, and from an inspection made during October, 1911, the results obtained are apparently remarkably good. No protection was used. Back filling was placed directly against waterproofing.

UNION AND SOUTHERN PACIFIC SYSTEMS.

Brick Depot Building: Coating brick walls on interior with asphaltum paint, before applying plaster; the paint used was Toch Brothers B. I. W., applied with spraying machine or three-coat work with brush. The cost of the work was 11 to 13 cents per sq. yd. applied with spraying machine. The work was done in 1907 and at last inspection, September 30, 1911, the plaster was found to be dry and decorating in good condition.

Hospital Building Basement: Used 5 per cent. Medusa compound, first mixed dry with cement, then added to other aggregate, proportion one part cement, one part sand and five parts stone, size of stone ¾-in. to 1¼ in. The mixture was so-called wet mixture (water appearing freely on surface). The work was done in 1909 and upon last inspection, September 28, 1911, the walls and floor were dry, no leaks and no moisture appearing. The cost of the work account waterproofing was increased $1.10 per cubic yard.

Oregon-Washington Railroad & Navigation Co.: Waterproofing concrete wall, built 1:3:5 mixture, blue cross cement, ordinary run of gravel and sand, maximum size of gravel passed 2-in. ring. Head of water 6 ft. Waterproofing consisted of Wunner's Bitumen Emulsion, mixed 2½ pints of this material with one bag of cement and 2½ cu. ft. of sand, adding water to plaster consistency applied to surface of wall; the work was done September 1, 1911, and at last inspection, October 28, 1911, showed small amount of surface water but no apparent leaks.

The cost was about 10 cents per sq. ft. of surface waterproofed.

PENNSYLVANIA LINES.

Enclosed are blueprints of statement corrected to include the waterproofed bridges, Twelfth to Twenty-sixth Streets, in our Chicago Track Elevation Work. This is a record of the method of waterproofing used in

WATERPROOFING BRIDGE FLOORS—METHODS USED AND RESULTS OBTAINED.

Pennsylvania Lines West of Pittsburg, Southwest System.

Street	Track No.	Method of Waterproofing	Year Applied	Result of Inspection		
				April, 1909	April, 1910	April, 1911
Ashland	1	6-ply Barretts Felt Concrete Top	1906	No leaks	No report	4 leaks
	2	4-ply Hydrex Felt Concrete Top	1906	No leaks	No report	4 leaks
	3	4-ply Hydrex Felt Concrete Top	1906	Leaks badly	No report	5 leaks
	4	5-ply Hydrex Felt Concrete Top	1907	Leaks badly	No report	4 leaks
	5	5-ply Hydrex Felt Concrete Top	1907	No report	No report	6 leaks
Paulina	1	4-ply Hydrex Felt Concrete Top	1906	No leaks	7 leaks	7 leaks
	2	4-ply Barretts Felt Concrete Top	1906	No leaks	8 leaks	6 leaks
	3	4-ply Barretts Felt Concrete Top	1906	No leaks	No leaks	8 leaks
	4	4-ply Hydrex Felt Concrete Top	1906	6 leaks	15 leaks	3 leaks
	5	5-ply Hydrex Felt Concrete Top	1907	No leaks	No leaks	5 leaks
	6	5-ply Hydrex Felt Concrete Top	1907	No leaks	No leaks	5 leaks
	7	5-ply Hydrex Felt Concrete Top	1907	26 leaks	2 leaks	4 leaks
	Driveway	3-ply Hydrex Felt Concrete Top	1906	No report	No report	8 leaks
	8	5-ply Hydrex Felt Concrete Top	1907	Several leaks	No report	4 leaks
	9	5-ply Hydrex Felt Concrete Top	1907	Several leaks	No leaks	
Wood	1	4-ply Hydrex Felt Concrete Top	1906	No leaks	13 leaks	10 leaks
	2	4-ply Barretts Felt Concrete Top	1906	16 leaks	9 leaks	10 leaks
	3	4-ply Hydrex Felt Concrete Top	1906	4 leaks	No leaks	10 leaks
	4	4-ply Hydrex Felt Concrete Top	1906	Several leaks	No leaks	10 leaks
	5	5-ply Hydrex Felt Concrete Top	1907	No report	No report	10 leaks
Lincoln	1	4-ply Hydrex Felt Concrete Top	1906	Leaks very badly	4 leaks	7 leaks
	2	4-ply Barretts Felt Concrete Top	1906	Leaks very badly	3 leaks	7 leaks
	3	4-ply Hydrex Felt Concrete Top	1906	Leaks very badly	4 leaks	11 leaks
	4	4-ply Hydrex Felt Concrete Top	1906	Leaks very badly	10 leaks	17 leaks
	5	5-ply Hydrex Felt Concrete Top	1907	Leaks very badly	No leaks	5 leaks
	6	5-ply Hydrex Felt Concrete Top	1907	Leaks very badly	No leaks	10 leaks
	7	5-ply Hydrex Felt Concrete Top	1907	Leaks very badly	No leaks	19 leaks
	Driveway	3-ply Hydrex Felt Concrete Top	1906	Leaks very badly	No report	10 leaks
	8	5-ply Hydrex Felt Concrete Top	1907	Leaks very badly	2 leaks	10 leaks
	9	5-ply Hydrex Felt Concrete Top	1907	Leaks very badly	No report	9 leaks
Robey	1	4-ply Hydrex Felt Concrete Top	1906	No leaks	15 leaks	7 leaks
	2	4-ply Barretts Felt Concrete Top	1906	No leaks	No leaks	26 leaks
	3	4-ply Hydrex Felt Concrete Top	1906	24 leaks	No leaks	5 leaks
	4	4-ply Hydrex Felt Concrete Top	1906	Several leaks	1 leak	19 leaks
	5	5-ply Hydrex Felt Concrete Top	1907	No report	No report	19 leaks
Hoyne	1	4-ply Hydrex Felt Concrete Top	1906	Leaks very badly	4 leaks	13 leaks
	2	4-ply Barretts Felt Concrete Top	1906	Leaks very badly	1 leak	18 leaks
	3	4-ply Barretts Felt Concrete Top	1906	Leaks very badly	No leaks	6 leaks
	4	4-ply Hydrex Felt Concrete Top	1906	Leaks very badly	15 leaks	18 leaks
	5	5-ply Hydrex Felt Concrete Top	1907	Leaks very badly	No leaks	6 leaks
	6	5-ply Hydrex Felt Concrete Top	1907	Leaks very badly	No leaks	19 leaks
	7	5-ply Hydrex Felt Concrete Top	1907	Leaks very badly	8 leaks	19 leaks
	Driveway	3-ply Hydrex Felt Concrete Top	1906	Leaks very badly	No report	9 leaks
	8	5-ply Hydrex Felt Concrete Top	1907	Leaks very badly	No leaks	9 leaks
	9	5-ply Hydrex Felt Concrete Top	1907	Leaks very badly	8 leaks	35 leaks
Leavitt	1	5-ply Hydrex Felt Concrete Top	1906	Leaks very badly	18 leaks	9 leaks
	2	5-ply Hydrex Felt Concrete Top	1906	Leaks very badly	9 leaks	22 leaks
	3	4-ply Barretts Felt Concrete Top	1906	Leaks very badly	2 leaks	22 leaks
	4	5-ply Hydrex Felt Concrete Top	1906	Leaks very badly	5 leaks	12 leaks
	5	5-ply Hydrex Felt Concrete Top	1907	Leaks very badly	No report	13 leaks
Oakley	1	Iron Bark Concrete Top	1905	No leaks	No leaks	3 leaks
	2	Iron Bark Concrete Top	1905	No leaks	14 leaks	6 leaks
	3	5 ply Hydrex Felt Concrete Top	1906	No leaks	No leaks	6 leaks
	4	4-ply Barretts Felt Concrete Top	1906	Leaks badly	No leaks	6 leaks
	5	5-ply Hydrex Felt Concrete Top	1907	Leaks badly	No report	17 leaks
Western	1	5-ply Hydrex Felt Concrete Top	1907	No leaks	5 leaks	8 leaks
	2	5-ply Hydrex Felt Concrete Top	1907	10 leaks	3 leaks	9 leaks
	3	4-ply Barretts Felt Concrete Top	1905	No leaks	No leaks	9 leaks
	4	4-ply Barretts Felt Concrete Top	1905	Several leaks	No leaks	23 leaks
	5	5-ply Hydrex Felt Concrete Top	1907	Several leaks	No report	33 leaks

Note.—Bridges located in Chicago.

WATERPROOFING BRIDGE FLOORS—Continued.

Street	Track No.	Method of Waterproofing	Year Applied	Result of Inspection		
				April, 1909	April, 1910	April, 1911
Marshall	1	5-ply Hydrex Felt Concrete Top	1908	No leaks	No leaks	No leaks
	2	5-ply Hydrex Felt Concrete Top	1908	No leaks	1 leak	No leaks
	3	5-ply Hydrex Felt Concrete Top	1908	No leaks	No leaks	No leaks
	4	5-ply Hydrex Felt Concrete Top	1908	No leaks	No leaks	No leaks
34th	1	Concrete and Asphalt	1904	Leaks very badly	Leaks very badly	8 leaks
	2	Concrete and Asphalt	1904	Leaks very badly	Leaks very badly	8 leaks
	3	Concrete and Asphalt	1904	Leaks very badly	Leaks very badly	10 leaks
	4	Concrete and Asphalt	1904	Leaks very badly	Leaks very badly	8 leaks
35th	1	Concrete and Asphalt	1904	Leaks very badly	Leaks very badly	8 leaks
	2	Concrete and Asphalt	1904	Leaks very badly	Leaks very badly	8 leaks
	3	Concrete and Asphalt	1904	Leaks very badly	Leaks very badly	9 leaks
	4	Concrete and Asphalt	1904	Leaks very badly	Leaks very badly	7 leaks
36th	1	Concrete and Asphalt	1904	Leaks very badly	Leaks very badly	6 leaks
	2	Concrete and Asphalt	1904	Leaks very badly	Leaks very badly	8 leaks
	3	Concrete and Asphalt	1904	Leaks very badly	Leaks very badly	7 leaks
	4	Concrete and Asphalt	1904	Leaks very badly	Leaks very badly	6 leaks
Archer	1	Concrete—Wire Mesh	1904	No leaks	3 leaks	No leaks
	2	3-ply Hydrex Felt	1904	No leaks	No leaks	1 leak
	3	3-ply Hydrex Felt, no Concrete on Top	1904	No leaks	No leaks	1 leak
	4	Concrete and Asphalt Mastic	1904	No leaks	No leaks	No leaks
Western	1	Concrete—No Waterproofing	1905	Leaks very badly	3 leaks	39 leaks
	2	Concrete—No Waterproofing	1905	Leaks very badly	16 leaks	36 leaks
	3	Concrete—No Waterproofing	1905	Leaks very badly	2 leaks	31 leaks
	4	Concrete—No Waterproofing	1905	Leaks very badly	6 leaks	30 leaks
Normal	1	Asphalt Mastic	1904	No report	15 leaks	30 leaks
Wallace	1	Asphalt Mastic	1904	No report	No leaks	No leaks
Lowe	1	Asphalt Mastic	1904	No report	14 leaks	36 leaks
Union	1	Asphalt Mastic Blocks	1904	No report	9 leaks	27 leaks
Emerald	1	Asphalt Mastic Blocks	1904	No report	20 leaks	6 leaks
	2	Asphalt Mastic Blocks	1904	No report	8 leaks	15 leaks
	Side Track	Hydrex Felt	1907	No report	4 leaks	12 leaks
Halsted	1	Hydrex Felt	1906	No report	1 leak	No leaks
Mill	All Tracks					
Sandusky		6-ply Barretts Felt, Brick on Top	1909		7 small leaks	24 small leaks
Darby		6-ply Barretts Felt, Brick on Top	1909		1 small leak	7 small leaks

Note.—Above-named bridges located in Chicago, excepting last three, which are in Columbus.

all of our track elevation bridges, and the results of inspections made from time to time thereafter.

All of the bridges were of trough floor, the troughs being filled with concrete, the waterproofing applied, and a protection coat of concrete or brick added on top of the waterproofing.

The cost of applying this waterproofing was as follows:

Twelfth Street	51.3 cents per sq. ft.
Ogden Avenue	50.0 cents per sq. ft.
Fifteenth Street	47.4 cents per sq. ft.
Sixteenth Street	49.3 cents per sq. ft.
Eighteenth Street	43.1 cents per sq. ft.
Twenty-first Street	39.3 cents per sq. ft.
Twenty-second Street	33.3 cents per sq. ft.
Twenty-third Street	57.3 cents per sq. ft.
Twenty-fourth Street	48.3 cents per sq. ft.
Twenty-fifth Street	48.4 cents per sq. ft.
Twenty-sixth Street	70.0 cents per sq. ft.

The above costs cover the concrete filling in the troughs, waterproofing the protection coating of concrete or brick, and the concrete parapet walls at the ends of the bridges. We have not added any material or substance to concrete, to make it impervious. We have not used a percentage of hydrated lime in any of our concrete, in an endeavor to make it impervious.

METHODS OF PATCHING AND REPAIRING PLAIN AND REINFORCED CONCRETE.

Your Committee having been instructed to collect data and prepare a report on "Methods of Patching and Repairing Plain and Reinforced Concrete," reports as follows:

A circular letter, under date of July 14, 1911, was sent to members of the Association, requesting information on this subject, to which letter more than one hundred replies have been received. Nearly all of the replies contain useful information, but as the same methods are frequently described by several writers, a selection has been made from these replies and is presented as an appendix to this report.

The various methods referred to may be described as follows:

(1) Wet Method: The surface of the old concrete is thoroughly roughened, cleaned and drenched with water and covered with a cement grout. Then the new concrete is mixed to a sloppy consistency and applied, being held in place till set by forms, as required.

Comment: From the reports received it appears that many successes and many failures have followed this method. Where it has been successful, that result probably has been due to painstaking care and expense being employed in the preliminary cleaning and thorough wetting of the old concrete surfaces before the new concrete is applied.

(2) Moderately Dry Method: The surface of the old concrete is thoroughly roughened, cleaned and drenched with water and powdered with cement or painted with cement grout—after which the new concrete is applied and thoroughly tamped against the old surface. Generally, such patches are kept moist by sprinkling them with water for several days.

COMMENT: The same comment applies here as to the wet method.

(3) DOWEL METHOD: This is a modification of the two preceding methods and is generally used for other than horizontal surfaces, although it may be applied to the latter. The new concrete may have any consistency to meet the particular conditions or the ideas of the Engineer in charge, but usually a fairly wet concrete is used. This method includes drilling holes and setting dowels into the old concrete, with projecting ends to engage into the new concrete. Sometimes steel bars or metal fabric are connected to these dowels to further insure permanency of the patch.

COMMENT: This method can be made uniformly successful, but cannot always be applied. Where any considerable mass of new concrete is to be connected to old concrete this is the only safe method to pursue.

(4) WEDGE METHOD: This method includes the cutting out of defective concrete in such a manner as to undercut the surrounding good concrete so that the new concrete will be held in place, when set, by the shape of the binding edges of the old concrete.

COMMENT: The difficulty of undercutting concrete so as to secure such edges is too great to make this method applicable in ordinary cases, and, except where a considerable depth of new concrete is to be put in, such undercutting could not be successfully done, as concrete cannot be cut so as to leave sharp, clean edges.

(5) CLEANING WITH STEAM: This is a method of cleaning surfaces of old concrete preparatory to putting on a patch of new, or of cleaning the top of a rough concrete floor before applying the "finish coat." The surface of the old concrete is brushed as clean as possible with stiff brushes and then gone over at least twice with a steam jet—an ordinary piece of half-inch gas pipe makes a very satisfactory jet nozzle. This short length of pipe is connected to a steam hose so that it can be readily moved about. The steam is supplied by the boilers of the mixer or hoisting engines. The steam will clean and heat the concrete surface, leaving it perfectly dry, so it is important to thoroughly drench the surface with water after cleaning with steam. In cold weather it is found advantageous to use hot water. Immediately after the surface is thoroughly cleaned and drenched, the new concrete is applied.

COMMENT: Excellent results have followed the use of this method of cleaning, but it is essential that the surface of the old concrete be thoroughly drenched with water after using the steam jet, otherwise the new concrete will not adhere to the old.

(6) CLEANING WITH ACID: This method includes washing of the surface of the old concrete with a solution of hydrochloric (muriatic) acid (one part acid to two parts water), after which the surface must be carefully and thoroughly washed to remove any free acid.

COMMENT: This is a very commonly applied method of cleaning old concrete surfaces preparatory to placing new concrete against them, and, by many, is considered the only safe one to use, especially where a "finish coat" is to be put on after the concrete base is set.

CONCLUSIONS.

Your Committee presents the following conclusions as to the methods of repairing defective or worn surfaces of concrete:

(1) In all cases the surface to be repaired must first be thoroughly cleaned of all loose material, laitance and dust and the clean, rough, sound concrete exposed to receive the patch. Probably the best method of cleaning is by means of a steam jet.

(2) After cleaning, the surface to be repaired must be thoroughly saturated with water, not simply moistened, but so thoroughly drenched that the old concrete will not absorb water from the new mortar or concrete used in patching. If possible, the surface should be kept covered with water for several hours.

(3) If the repair or patch is to be made on a vertical or sloping surface and is not to be more than 1½ in. thick, the surface of the old concrete, while it is still wet, should be spattered or splashed with a cement grout, following this immediately with a fairly stiff plaster coat of mortar made of the same proportions of cement and sand as was used in the original concrete, but never richer than 1 cement to 2½ sand. This plaster coat should not be thicker than ½-in. and each coat should be forced into the surface, but not dragged with a trowel. The surface of each coat, except the final coat, should be "scratched" to give a bond for the next coat. This plastering should preferably begin at the top and progress downward, and only enough time be allowed to permit each coat to receive its initial set before the next coat is applied. The final coat should be finished with a wooden float and only enough water used to properly finish the surface. This patch should be kept damp and protected from sun or frost till fully set up.

(4) If the repair or patch or "finish coat" is to be made on a horizontal or nearly horizontal surface, the surface of the old concrete should be slushed and broomed with a thin cement grout, following this immediately with a *wet* mortar made of 1 part cement and 2½ parts sand or granite screenings and of the full thickness required (not less than ½-in. thick, however). When this mortar begins to take its initial set, it should be floated or troweled to such a finish as may be desired.

(5) If the repair or patch is to be made on a vertical or sloping face and is to be more than 1½ in. thick, it will be advisable to embed dowels into the old concrete, as deeply as the thickness of the proposed patch, and spaced sufficiently close together to firmly anchor the patch to the old concrete. The dowels must be wedged into the old concrete and it will be advisable to fasten wires, metal fabrics or bars to the dowels, in the case of extensive patching, as an additional safeguard. The patching may then be done with mortar without forms, or with wet concrete supported by forms, depending upon the thickness and the extent of the patch.

(6) If the repair or patch is to be made on a horizontal or nearly horizontal face and of considerable thickness, dowels may be used, or

the concrete may simply be reinforced by fabric or bars without using dowels—treating the patch as a block of masonry.

(7) Care must be taken not to have thin edges on patches. To avoid this, it may be necessary to cut out sound concrete around a place to be patched, so as to give deep edges to the patch. If possible, the edges should be undercut.

ABSTRACT OF REPLIES.

Lincoln Bush, Consulting Engineer: "During the years 1900 to 1909, inclusive, the Lackawanna Railroad put in 907,000 cu. yds. of concrete. In building this masonry the general practice for concrete work done from 1900 to 1903 was to make the body of the masonry in proportions of 1:3:5, with a 2-in. surface finish in the proportions of about 1:2:2.

"The concrete built from the years 1903 to 1909, inclusive, which was generally in the proportions of 1:3:5 for the entire wall without any 1:2:2 mixture for a facing coat, has given by far better results than the work done with the 2-in. facing. My observation and experience show that the defects and shelling off of the 2-in. facing may not take place for a period of two or three years after the work is finished and that these defects and the shelling off continue.

"I advocate very strongly the use of a uniform mixture for the entire wall, omitting the surface coat of richer proportions and, if it is desirable and necessary to have a special surface finish for ornamentation or other purpose, to obtain such finish by bush hammering, treatment with acid or rubbing and washing while concrete is green, using crushed stone of such size as will give the desired surface effect."

Frank H. Alfred, General Superintendent, Cincinnati, Hamilton & Dayton Railway: "Small imperfections in finish, we repair with stiff cement grout immediately after the removal of the forms. We aim to simply fill in small cavities, not by plastering, but by working the grout into each individual cavity, finishing afterwards, while the grout is green, by rubbing with a small block of wood.

"Larger cavities we fill whenever weather conditions are favorable. In filling such cavities, we aim first of all to thoroughly clean the cavity of all loose stone, cement and dirt. We are very particular about cleaning the cavity, using for the purpose a weak solution of acid, if necessary, later washing all remaining acid from the cavity. We then use one to two grout or a lean concrete mixture, mixed rather stiff. This mixture we are very particular to thoroughly mix, that is, if mixing by hand, where three turnings would suffice for ordinary concrete, we give the material intended for patching some eight or a dozen turnings. In depositing this material in the cavity we seldom use anything resembling a form to retain it in place, but put the material in with trowels in small layers, thoroughly working it into place. If the mixing and depositing is thoroughly done, such repairs will be permanent."

W. J. Harahan, Vice-President, Erie Railroad: "At Hornell, in 1907, one of the forms on the retaining walls, over a section 12 ft. in height and 20 ft. in length, bulged about 5 in. at the bottom near the center and the bulge radiated from this point to nothing at the sides and top. On account of being on a sidewalk and the appearance very noticeable, this extra width was scabbled off; this scabbling left a rough and uneven surface. The finishing surface was put on with a mixture of one part cement to three of sand made into a dry mortar; the surface of the rough wall was wet down thoroughly while finish was being applied. Commencing at the top and at one end of the section, this mortar was put on with a float, a small amount at a time, starting at the top and carrying it to the bottom in sections of about 2 ft. in width; the work was carried on uninterruptedly in this manner until the whole area was covered. The thickness of this veneer is generally one inch, but there are places where

the scabbling was irregular and where it is from 2 to 3 in. thick in spots. There has been no indication of checking and the appearance of the wall is generally the same in color as the remainder, which was made of concrete 1:2½:5, and there is no reason to believe that, from this time on, there will be any failure.

"At Buffalo, on an abutment composed of a mixture 1:2½:5, after the forms were removed, a point about 2 ft. above the foundations indicated a break in the mixture in that it showed a sand streak. The entire abutment was gone over with bush hammer as a test, but there was not further indication of this predominance of sand. The point referred to was cut over an area 4 ft. high, 8 ft. long and 18 in. deep from the face of the wall. In taking this out 2 in. of the hard concrete was removed to be sure that all of the sand had been taken out, and a cross-section showed that at 8 in. back from the face the material was removed for a distance of 6 inches higher and wider than the opening at face of wall and then cut back 10 in. deeper, this in order to dove-tail the new concrete into the old. It happened that there were some one-inch corrugated bars left over from reinforcement. From this three vertical and two horizontal rods were inserted about on the line of the offset; that is, about the middle of the hole. Then it was filled in with 1:2:4 concrete and after setting up was bush hammered. This work was done on June 10, 1911, examination made on July 22, 1911, did not show any indication of shrinkage of the new concrete from the old concrete, and no indications, by sound, of any cavities."

L. W. Walter, Cement Inspector, Erie Railroad: "Of these three processes, that of 'pouring' permits of the use of mortar or concrete and is resorted to when the surface to be bonded is very irregular or when the bulk of the applied material is too great to permit of plastering or tamping. This process involves the erection of forms and the depositing of concrete or mortar in the usual way, but further requires that the material be very wet, and that it be agitated near the surface of the old concrete to bring the new material in the closest possible contact with the old. This method is frequently unsuccessful and should be resorted to only when the bulk of the applied material is so great as to make the cost of plastering or tamping prohibitive. It is of course understood that when this or any other method is used it is necessary to remove all loose particles from, and to thoroughly drench the surface of the concrete.

"In the process of plastering on old concrete surfaces which have been scabbled or roughed, both the conditions and the requirements are so varied that results are frequently not satisfactory. Plaster will adhere to surfaces prepared by furring or roughing, as is customary in preparing the scratch coat to receive another coat in straight plaster work, but in plastering irregular concrete surfaces it is necessary to use very wet mortar. This gives it a tendency to loosen from the surface, by its own weight, thereby forming hollow areas which will be further loosened by frost, where there is considerable moisture present, or by expansion and contraction due to temperature changes.

"The practice of tamping mortar against old concrete surfaces, whether it be to fill voids caused by air bubbles, or whether the surface be honeycombed or on surfaces made rough by scabbling, is one which I would personally recommend, as I have tried it under varying conditions and have not had a failure. In tamping mortar to rough surfaces I would proceed in the following manner: Working downward from the top of the area to be treated I would remove all loose particles and would wash the surface of the old concrete with a brush. The sand and cement for use in the mortar should be the same kind and proportions as that used in the concrete, provided it be not richer than 2½ parts of sand to one part of cement, and should be thoroughly mixed dry and water added by sprinkling until a semi-plastic consistency is had. In tamping the mortar

against the surface to be treated, I would work downward from the top of the area in order that the water used in wetting the surface of the concrete would not run down over the newly applied coat. When the surface has been brought to the proper plane, it should be floated with a wooden float, and only such amount of water should be used in the final floating as may be necessary to produce a dense surface. This water may be applied by means of a brush or by dipping the float in water.

"It is found in practice that a rather dry mortar, such as may be tamped, and not plastered, on a concrete surface, is less apt to loosen from contraction and expansion due to temperature changes and will more nearly resemble, in color, the adjoining natural surface.

"In such work as renewing the top or wearing which has loosened from the base of concrete pavements, on account of its having been placed after the base had set, the tamping process is a success. It is necessary, however, that the base of the concrete be firm, and advisable that the base be washed with a neat cement wash and the new top be well floated. This, in my opinion, is the most difficult patch work to be encountered and is the best argument I have to offer in favor of using, for patch work, a relatively dry mortar.

"For patching honey-combed surfaces I would recommend tamping to the exclusion of the old practice of plastering."

J. M. Meade, Engineer Eastern Lines, Atchison, Topeka & Santa Fe Railway: "In one small abutment the bridge foreman allowed the weight to be placed upon it too soon, when a wedged shaped piece of the abutment broke out with about half of the bridge seat as the base, and extending down three or four feet on the face of the abutment, to the point of the wedge. The broken face was thoroughly roughened up and form built around it and concrete of the same mixture was very thoroughly tamped into position.

"On some reinforced work we did last winter the section foreman knocked off a part of the form in connection with his track work, and in doing so knocked off several corners of the concrete. We built up forms around these and thoroughly tamped in a rich mixture of equal amounts of sand and cement, and today the break cannot be detected.

"Several concrete steps in Newton, Kansas, were replaced several years ago by roughening the surface and putting in nails for dowel pins. This was thoroughly tamped with a rich mixture and has never shown any signs of failure.

"The secret in patching concrete seems to have been in having a rough surface to work on, and in thoroughly tamping the concerete and putting in dowels or anchors, of any kind, wherever possible. Also in leaving it in the forms until it was thoroughly set."

F. E. Schall, Bridge Engineer, Lehigh Valley Railroad: "A double track ribbed abutment, supported by piling, broke in two about the center line, and opened up a crack about 1½ in. wide (due to settlement and leaning of piling in foundation); after movement of piling ceased, a V-shaped opening about one foot wide and about 6 inches deep was cut in the face of the abutment and that opening filled with comparatively dry concrete; after setting of this concrete, the crack was filled with concrete grout. A slight crack due to contraction of concrete appeared along the edges of the V-shaped patch but is of no consequence. The patch has been in place about 1½ years and is giving satisfaction."

H. F. Hamilton, Resident Engineer, Great Northern Railway: "I wish to say that I had occasion a few days ago to look over Bridge 434, and found that the new concrete had adhered very nicely to the old surface and was apparently as solid as if placed at one time. Method used was to scabble off with a pick and bull point the concrete affected by the frost.

Then to wash the surface exposed with water, scrubbing with a stiff broom. This was then gone over with 1:3 solution of muriatic acid and again washed. New concrete was applied as soon afterwards as possible and put on very wet. At two or three places about four feet above the ground line there was a hollow sound to the concrete, and it appeared that there was not a very good bond in about an inch or so from the surface. As there was a slight bulge in the surface of the wall, I think this is some additional put on with a trowel after the forms were removed. I believe the above methods will give good results, but this depends on how clean the old surface is made and the keeping of the new concrete damp for a week or so after being placed."

J. A. Atwood, Chief Engineer, Pittsburg & Lake Erie Railroad: "Cut out all loose concrete and wash it off thoroughly, then apply a thin wet mixture of mortar of about one to one, allowing it to set for about an hour or more in order that it will adhere to the old concrete and not slip away when the concrete is put in. We then use a wooden float to rub the outer surface. If the patches are too large we insert steel dowels in the old concrete."

E. A. Hadley, Engineer of Design, Missouri Pacific Railway: "Thoroughly clean the surface of the old concrete with a stiff brush, remove all loose particles and foreign material. If the surface to be patched was smooth, the same was made rough by the use of hand drill.

"After the surface was prepared in this manner, the same was washed down with clean water, and a thin layer of cement mortar mixed one to two, spread on the surface, and a rich mixture of concrete immediately placed on the bed of the mortar.

"The tops of several retaining walls were repaired in this manner under my direction, and the face of a bridge pier, on which the forms had bulged, was cut down to a true surface and patched up in this manner.

"This work was done in the early fall of 1909 and was examined by me personally in December, 1910, and it was found that the patched surfaces were in perfect condition, with no signs of cracking or peeling, and no hollow sound was emitted when the surface was struck a sharp blow with a light hammer."

C. E. Cartwright, Consulting Engineer: "The surface of the old concrete is carefully picked so that all loose material is removed and irregular holes are cut so that a mechanical bond will be made between the old and new concrete. If the concrete will be subject to blows iron dowels will be set at different angles and well grouted.

"Before placing the new concrete the old surface will be thoroughly soaked with water for a couple of days. It will then be well brushed out with a steel brush and water and immediately before pouring the concrete a coat of neat grout will be brushed in.

"If the repair is large reinforcing steel will be used, the ends being well grouted into special holes drilled for the purpose."

F. L. Wheaton, Engineer of Construction, Delaware, Lackawanna & Western Railroad: "We do not allow surfaces to be washed or plastered with either neat cement or cement and sand after the forms are removed, as this invariably scales off in time and leaves an unsightly appearance. We do in some cases allow surface to be smoothed by use of plain water and carborundum, or cement bricks, rubbing off the white lime dust after surface is dry, but prefer surfaces to remain without treatment of any kind, which can be done if sufficient care is taken with forms.

"Where bony or porous places occur in face, due to improper spading or a leak in forms, which allows cement and sand to escape, we require voids to be filled immediately upon removal of forms with cement mortar of same proportions as used in the body of concrete and smoothed with

wooden float, not troweled. We seldom have any trouble with this mortar falling out and if done in time is seldom noticeable.

"One of the worst defects in concrete faces, and one which rarely develops until some time after the completion of the structure and, therefore, is hard to repair, is caused by the failure to remove the sludge which invariably rises to the surface of wet concrete and forms a slimy coating of variable thickness at the end of each day's work. If this is allowed to remain, and the next day's work deposited thereon, it will later dissolve, leaving a more or less ragged line of demarkation on the surface. While this is inexcusable, it sometimes occurs and we then chisel it out in the form of a dovetail, filling with cement mortar and stone screenings, taking care that mixture is not made too rich, otherwise, there will always remain too great a contrast in color. This should be floated off with wooden float or wire brush so as not to leave a glossy finish. We do not depend on new concrete adhering to old, but cut out imperfection to sufficient depth and dovetail in the patch."

Hunter McDonald, Chief Engineer, Nashville, Chattanooga & St. Louis Railway: "The only method which I have tried for restoring the surface which has been worn off or cracked away by failure of the top coating to adhere to the concrete beneath, is to apply to the old concrete a solution of one part hydrochloric acid and two parts of water, permitting it to stand about fifteen minutes, then washing it off thoroughly and applying the top finish. This has been tried in only a few isolated cases and the success of the efforts has not been sufficiently demonstrated for lack of time.

"I have understood that in a reinforced concrete building the floor finish put on the rough surface by this method has, in many instances, come loose. Whether this is due to bad workmanship or an imperfect process I am unable to say.

"In finishing the floors of a reinforced concrete warehouse I required that the top surface should be applied within three hours after the laying of the concrete. This plan has worked well in every instance, except where rain came up and roughened the floor after the finishing had been done. These rough places I have endeavored to grind out, but have found no successful means of doing so. Efforts to patch them out by applying additional finish have been unsuccessful on account of the fact that we did not remove the top coating for a sufficient depth. The feather edges of all patches will grind off."

G. W. Vaughan, Engineer of Maintenance of Way, New York Central & Hudson River Railroad: "It is the usual custom, when necessary, to patch or add to old concrete, to use a hose with water under pressure, or a brush with water and thoroughly clean the old concrete with a view of removing every particle of loose material and dirt and leaving same perfectly solid and clean. Then we dust dry cement over the old work and scrub it in thoroughly until all of the spaces in the surface of the old concrete have been filled with the dry powder. This is slightly moistened and the new concrete applied.

"In building concrete abutment piers or on retaining wall work, when for any reason, the work is stopped for a time and the top becomes set, it is usually customary to thoroughly wash the set concrete and make it perfectly clean, then mix up a thin grout and pour it on, after which the fresh concrete may be applied. We have experienced very little trouble with this method and it seldom shows a seam. However, to build an extension on an abutment or a retaining wall at the end, a seam nearly always develops.

"Sometimes when applying a patch we have been successful in handling same somewhat different than first described, by simply cleaning away all loose particles of concrete, then thoroughly wetting the old con-

crete and applying a small quantity at a time of new, letting it partially set before putting on more; following this process until the work has been built out to its original surface. This would apply particularly to large patches, where if all applied at once, its own weight might cause it to sag and fall away from the old work, unless we went to the expense of putting in dowels.

"For instance, at Poughkeepsie we have patched the underside of the protection concrete in this manner and it has been most successful. The conditions are extremely bad at this place on account of the old concrete being covered with a coat of soot, grease and smoke from the exhaust of engines. This was scrubbed with lye and water and then washed off with the clear water before applying the patch. We would not have any trouble with this under ordinary conditions, as it lasted well until the cold weather came on, so that when the hot exhaust from the locomotives, the stacks standing directly under the concrete, came in contact with same, the temperature was so suddenly changed that it caused the concrete to shell off. We do not believe that patched concrete can be made to stand under these conditions.

"In some instances, the surface of the concrete to be repaired, has been first roughed up and then kept thoroughly saturated with water for several hours. Then a coating of cement mixed two to one is thoroughly troweled on and kept moist for a considerable period of time. A very good way to keep the surface moist is to place several layers of burlap on top of the fresh surface and keep the burlap soaked with water.

"Where the surface to be repaired is of a considerable thickness, 1½ in. and upward, anchor pins are used, spaced about four to a square foot of surface. This is particularly effective where the surface is perpendicular.

"In some cases our experience has been that about the only successful way to do this kind of work is to cut out the old work, dove-tailing it and putting in anchor bolts and care should be taken to see that the old work is roughened up and dove-tailed, care being taken to avoid feather edging. Also in doing this class of work care should be taken to see that the new concrete is not mixed too soft, as it should be of such consistency that it can be lightly rammed.

"In repairing concrete work, where netting is used on the outer surface, care should be taken to see that the old concrete is removed back of the netting, so as to get a bond with the netting.

"Ordinarily the methods of patching and repairing, as outlined above, have been successful."

F. L. Thompson, Engineer of Bridges and Buildings, Illinois Central Railroad: "In general, our practice in patching small surfaces is as follows: A mortar is made up with the same proportions of cement and sand as has been used in the concrete which is to be patched. This mortar is quite stiff and considerable pressure is used in applying it to the cavity which is first cleaned and thoroughly wet. After the mortar has partially set the surplus is rubbed off with a wooden float, leaving the surface of the patch flush with the surface of the wall.

"To lighten the patch and make it as near the color of the old work as possible, a small quantity of lime paste is added to the mortar. Where there are deep cavities, it is sometimes necessary to partly fill them and after the mortar has set make a second application."

H. Rettinghouse, Division Engineer, Chicago & Northwestern Railway: "I have had several cases, when horizontal surfaces, especially bridge seats had been damaged by frost, to a depth of from four to eight inches. After removing the frozen and spoiled concrete, we chipped the surface down to a nearly uniform level, equal to the deepest frozen spot. In one case which I have in mind, the entire bridge seat of a three track

bridge had been severely damaged by frost. We placed dowel pins in squares of two feet, securely anchoring them in the sound concrete, then carefully and thoroughly cleaned and washed off the entire surface and placed new concrete. We performed work of that kind early this spring (in April), and recent inspection would indicate that it is an entire success

"During the past three years, we have successfully jacketed with concrete, old masonry, which had badly deteriorated. The method pursued was the use of hook dowel pins and expanded metal. The jackets varying from ten to fourteen inches in thickness. We took great care to remove all deteriorated and loose portions of masonry, cleaning out joints, etc., and have been entirely successful in securing a perfect adhesion of concrete jackets to the old masonry, so much so, indeed, that we are gradually treating all our more or less deteriorated masonry of bridges on the Iowa Division in this manner. We have, unfortunately, a great deal of poor stone in bridge masonry. Some years ago, before I came to this territory, there had been a great many back walls of bridges built up with from four to eight inches of concrete on top of old masonry, on account of track being raised by ballasting. In all of these cases no dowels were used and the method proved a failure."

C. H. Fake, Chief Engineer, Mississippi River & Bonne Terre Railway: "In a larger case I was successful, where, in building two abutments for a deck girder bridge, the abutments were found to be two feet too far apart. The abutments were both on solid rock, so there was no danger from uneven settlement and a two-foot slab was patched on as follows: The face of one of the abutments was scabbled until thoroughly roughened. Holes about 1½ to 2 in. diameter were drilled in the roughened face a foot to a foot and a half deep and an area of a hole to 1½ to 2 sq. ft. They were not drilled in rows or to line, but irregular and promiscuously. Bolts of 1¼ in. iron with swelled end and split, with wedges were driven into these holes, not tight enough to damage the old concrete but firmly enough so they could not be pulled out. These bolts were carefully grouted, leaving the ends stick out from 1 ft. to 22 in. The form was then built and concrete of the same proportions as the abutments was filled in and in course of a couple of months the girder was put in place. The end of the girder, 64 ft. long, rested on this patch which on one end of abutment is about 7 ft. high and other end 10 or more feet high. The work has been done between eight and nine years and no sign of separation has shown."

H. L. Kipley, Engineer of Construction, New York, New Haven & Hartford Railroad: "The method we have used with success is to knock off all loose concrete; go over the surface with a mason's point and break a new face on the stone aggregate; wash down the surface thoroughly with scrubbing brushes and a water, or better yet a steam jet; wet the surface until it has absorbed practically all the moisture the concrete will take up; paint on a wash of neat cement; as soon as it commences to set put on under considerable pressure a plaster coat of new concrete. (If any oil has been used around the concrete a steam jet is about the only method I know that will entirely remove it).

"By keeping the new concrete moist (not drenched) and protecting it from the direct rays of the sun by curtains or otherwise, we have met with fair success in patching old concrete using this method. Of course, concrete must be absolutely protected from frost during the work and for three or four days afterward."

L. B. Merriam, Civil Engineer, Winnipeg: "I have frequently used the ordinary method of thoroughly cleaning the surface to be patched,

then soaking the original concrete at the place where the patch is to be made. I believe my success has depended entirely upon using a sufficient quantity of water in the soaking process. The water should be applied at intervals or constantly for a period of at least ten hours, preferably for twenty-four hours before the patch is put on. Those failures that I have had indicated that the original concrete had robbed the new concrete of its water before the final set was completed owing to the application of water for too short a period prior to placing the patch. I have plastered large surfaces successfully where the body concrete was thoroughly saturated before applying the plaster."

George W. Kittredge, Chief Engineer, New York Central & Hudson River Railroad: "Our practice on all the breaks where there is a hole of not more than 2 in. in depth to fill up, has been to clean off the surface of the concrete thoroughly, wet it and then apply about a half inch of mortar, allowing this to stand until it has dried out slightly, when another coat of about the same thickness is applied; this process being repeated until the hole is filled up flush with the face of the concrete from which the piece has been broken, after which it is floated. In most cases the repaired spot can hardly be detected, and I do not know of any cases where the pieces have broken out again.

"At different times we have used the following method: Square out the holes, making the area at the back of the hole larger than on the face, and fill it up with mortar. This shape of hole served to key in the new piece. This method was not as satisfactory as the one which is described above, as the patches show more plainly, and it was also somewhat more expensive."

E. B. Temple, Assistant Chief Engineer, Pennsylvania Railroad: "At South Fork, Pa., we built a retaining wall in the winter of 1909-1910. The weather was unusually severe, and before the concrete set properly the surface concrete was frozen. In the spring, the face of the wall showed signs of disintregation; and, after a careful examination, it was decided to remove as much as possible of the faulty concrete. This was done by picking the surface with a small hand pick to a depth varying from 1 to 18 in. The body of the wall thus exposed was good substantial concrete, and was carefully cleaned. Dowels of steel were driven into this surface, the dowels being placed about 6 in. apart, and to these dowels a light reinforcing mesh wire was firmly attached. The forms for the face of the wall were then placed; and, after the concrete had been thoroughly wet, the forms were carefully backfilled with cement and sand in the proportion of approximately 1 part cement to 2 of sand. This wall has been standing for about fifteen months, and apparently is in as good condition today as when put in place."

A. Q. Campbell, Assistant Superintendent, Oregon Short Line Railroad: "The methods that I have used in this work have varied to a certain extent with the class and the nature of the material to connect with. The most successful method I have used has been the channelling of the old concrete, say one inch deep and one inch wide, or the width of a chisel, these channels to be made in the surface of the old concrete in the shape of a checker board, the size of the squares depending on the size of the surface to be covered.

"I successfully covered a depot platform in this way with 1½ in. topping, that has now been in service for four years with but one or two cracks coming in same. The success with which the covering is put on in the case of sidewalks or beams would depend very largely on the class of material used in the concrete and the nature of the old concrete. I have in some instances sprinkled the face of the old concrete with cement

before applying the patching mixture, which has acted very successfully. So much in cases of this kind depends on the nature of the old concrete and the personal factor of the man doing the work, as well as the material to be used in the patching mixture, that what may be successful in one place would not be successful in another. My experience has been that the best material for making a patching mixture is crushed screenings, of about the ratio of one to two. Where heavy masses are being joined together the channelling of the old mass has in most cases been sufficient to make successful bond."

T. E. Calvert, Chief Engineer, Chicago, Burlington & Quincy Railroad: "The old concrete is thoroughly cleaned and wetted and about ½-in. of mortar put on. When this has set enough to become stiff the surface is roughened with the point of a trowel and another layer of similar thickness put on; this is continued until the hole is filled, the surface being finished flush with the old concrete.

"We have patched holes 3 and 4 in. deep and with an area of 2 or 3 sq. ft. successfully. Some of this work has stood for three years without signs of trouble. We have not succeeded in making patches less than 1½ in. thick stick, as the mortar cracks and scales off."

G. J. Ray, Chief Engineer, Delaware, Lackawanna & Western Railroad: "The only extensive job which we have had to contend with was a concrete bridge consisting of several 33-ft. arches. The concrete in this structure showed signs of either poor cement or acid bearing water used in making the concrete, with the result that it scaled off in large quantities every year. It was an easy matter to dig down into the solid concrete, but if the solid concrete was exposed for any length of time it again would start to deteriorate. The entire structure was repaired by covering the same completely with from a foot to eighteen inches of reinforced concrete, the new concrete being bonded to the old by a large number of dowel pins, which were drilled into the old concrete and fastened in a substantial manner. This repair job has proved to be very satisfactory. To make the work permanent the entire outside of the old structure was excavated and properly waterproofed."

W. H. Courtenay, Chief Engineer, Louisville & Nashville Railroad: "Our practice has been that when the forms are removed we patch such surfaces where the mortar did not come out to the forms by merely washing them clean and plastering over the defective surface with fresh mortar. Such patches are unsightly, but they generally hold."

Fred G. Simmons, Superintendent, C. & M. of Way, Milwaukee Electric Railway: "One reason why new concrete does not adhere perfectly to old is that in hardening the fresh concrete shrinks in volume, pulling away from the contact sides and leaving air spaces between the two surfaces. These spaces are small at first, but with changes of temperature, vibration, etc., gradually widen out until there is not enough adhesion between the patch and the body of the concrete to hold the former in place. The metal mesh firmly attached to the main mass of concrete and being part of the patch overcomes this trouble."

J. P. Congdon, Supervising Engineer, Oregon Short Line Railroad: "Cut off the surface of the concrete to be patched so as to remove all dust and laitance and give a surface of good, hard concrete. Roughen this surface with pick or otherwise so that it will present pockets or irregularities into which the patch can key.

"Wet the surface thoroughly. Sometimes it is dusted with neat cement, but good results have been obtained without this. Patch the

spot with concrete or mortar, depending upon the size of the patch, of the same consistency and mixed in the same way as the original concrete. This will prevent difference in the contraction and expansion of the masonry and also keeps the color uniform providing the same cement is used.

"After the concrete is well set rub the surface down with a wooden float. The surface is usually wet with water, to which considerable cement has been added to give it the color of the concrete. Sometimes a cement or sand brick is used. Very good results have been obtained in this way on our work."

C. F. Loweth, Chief Engineer, Chicago, Milwaukee & St. Paul Railway: "The surface of the old concrete is first well roughened up with track chisels to secure the removal of all old mortar surface and any loose stones are at the same time taken out. The surface is then thoroughly wetted to avoid any danger of the removal of any moisture from the new concrete or mortar by capillary action. A thin wash of neat cement of about 1-16-in. thick is then painted on the roughened surface. To this is then applied a thin coat of about ¼-in. of mortar made in the same proportions as that used in the adjacent concrete. To this is immediately applied the new concrete which is well tamped into place. Whenever conditions are such as will permit it, small dowels are drilled into the old concrete to serve as anchors of the old and new work.

"Where a concrete surface has pockets in it which require patching, a mixture of mortar similar to that used in the balance of the work is employed, being mixed stiff as practicable to avoid shrinkage, and the face of the patch worked with a wooden instead of a steel float to secure a surface in harmony with the balance of the work."

Edwin F. Wendt, Assistant Engineer, Pittsburg & Lake Erie Railroad: "When the surface of a concrete structure fails on account of frost having had access to it before the concrete is thoroughly set, it is a doubtful question whether it can be resurfaced so that permanently good results are accomplished. This is also true in cases where surfaces have been damaged from any cause. If a small surface is to be repaired we have obtained good results by cutting out all damaged parts and, in addition, cutting into the surface from two to four inches, and if this does not pass reinforcing steel cut the sides of section taken out to an angle of about sixty degrees to the surface, then the surface to be repaired should be freed of all loose gravel and dust and thoroughly saturated with water, using a hose if good pressure can be obtained. If water pressure is not obtainable use a stiff brush and thoroughly wash the surface. Next we apply to this rough, clean, saturated surface a neat cement grout about the consistency of thick whitewash, using a good whitewash brush. This should be well rubbed in, then immediately applying a mortar of one of cement to two of good clean sand in half-inch layers, allowing each layer to take its initial set, roughening the surface before the succeeding layer is applied and carrying on this process until the original surface is reached. The patched surface should be kept moist and protected from the sun or anything adverse to good results in concrete structures, until the patched surface has taken its final set. We have applied this method of repairing to plain concrete, such as walls, roofs of bridges, machinery foundations, sidewalks, etc., and, in one particular case of patching a machinery foundation we found it intact after five years of use."

W. L. Darling, Chief Engineer, Northern Pacific Railway: "We have found that wherever concrete is patched or repaired in thin surfaces that failure almost surely results. Wherever concrete work has disintegrated on the surface or has become damaged, as it sometimes does by the action of ice on concrete that has not yet thoroughly set, it has been re-

paired by cutting out a block of sufficient dimensions then drilling dowels into the old structure, the bond between the two being assisted by roughing up the old concrete and cleaning with a wire brush."

Samuel Rockwell, Chief Engineer, Lake Shore & Michigan Southern Railway: "I have attempted this at a number of different times and under a number of different conditions, but have never had any very marked success, especially when the patches were small. It is largely the same problem as filling teeth, and, as with that, it is necessary to prepare a cavity in such a way that it will assist to hold the patch. Then, if the sides are carefully cleaned and wet, a patch can be put on that will hold and show but little, but all attempts at plastering up shallow holes without such preparation are abominations pure and simple, as is also any attempt to wash or plaster over the general surface of concrete."

W. S. Thompson, Division Engineer, Pennsylvania Railroad: "It has been my experience that such work is very unsatisfactory and I have never been successful in making a good job. In case the surface scales, it is usually better to bush-hammer the surface smooth and let it go. This applies to surface defects."

G. J. Bell, Division Engineer, Santa Fe: "Have never made any repairs that could be considered a success. We brush the loose particles from the concrete to be repaired, then drench with clear water until thoroughly soaked and sprinkle a little neat cement before the mortar or concrete is put on. Have never made any repairs that were entirely satisfactory."

R. B. Abbott, Division Engineer, Philadelphia & Reading Railway: "The first thing done is to scrape or pick off thoroughly all those portions of concrete. The damaged face is then roughened up and holes 6 in. deep drilled therein, spaced about 2 ft. apart. The diameter of each hole is roughly 4 in. and the outline is made irregular. Enough of the old work is removed so that the new coat will have a minimum depth of 1 in. Along the perimeter of the damaged surface, the concrete is cut out to a depth of 2 in. with a slight overhang so that the old concrete will tend to lock in the new. The damaged surface is then brushed with a 1:1 cement wash.

"Commencing at the extreme lowest point of the work the form is then built up 1 ft. at a time so that each filling can be thoroughly tamped. A mixture of one part cement to two parts fine sharp sand is used in the actual work of restoring the surface.

"After the material has set and the form been removed, the surface is again wetted and treated to a 1:2 cement wash. This is a refinement, however, and is only employed where the maximum of neat finish is required. For ordinary railroad work, we have not found it necessary except in cases where the boards used in the forming were rough and warped."

METHODS OF DEPOSITING CONCRETE UNDER WATER.

Pursuant to the instructions of the Board of Direction, letters and circulars of inquiry were sent to the members of the Association, requesting information on the subject of "Methods of Depositing Concrete Under Water." This inquiry embodied the following questions:

(1) Methods used for depositing concrete.

(2) Depth of water.

(3) Results.

(4) Precautions necessary to secure desired results.

(5) A statement of the cost of plant and relative cost of depositing concrete per cubic yard, as compared with concrete deposited by the usual methods, will be of value in this investigation.

Seventy-one replies were received, fifty-six of which contain information of value, covering nine methods of depositing, viz., bottom-dump bucket, tremie (a closed chute), sacks, sacks withdrawn, paper bags, open chutes, open depositing, pneumatic grouting of broken stone, concrete blocks. From an examination of the replies, the Committee draws the following:

CONCLUSIONS.

(1) Concrete may be deposited successfully under water, if so handled as to prevent the washing of the cement from the mixture.

(2) Cofferdams should be sufficiently tight to prevent current through the pit, and the water in the pit should be quiet.

(3) The concrete should be deposited in place either by means of a drop-bottom bucket or a tremie, and should not be allowed to fall through the water.

(4) Where a bucket is used, it should be carefully lowered to the bottom and raised to the surface, so as to cause as little disturbance as possible of the water.

(5) Where a tremie is used, it should be kept filled with concrete up to the top of the water level, and the discharge end should be kept buried in the freshly deposited mass to prevent emptying, and raised a few inches at a time as the filling progresses.

(6) The surface of the concrete must be kept as nearly level as possible to avoid the formation of pockets which will retain laitance and sediment.

(7) Where concrete is not deposited continuously, all sediment should be removed from the surface of the concrete, by pumping or otherwise, before depositing fresh concrete.

(8) The concrete should be a 1:2:4 mixture and of a "quaking" consistency.

(9) Freshly deposited concrete should not be disturbed.

(10) In open water, where the flow of water through the pit cannot be prevented, concrete should be deposited in cloth sacks.

An abstract of replies containing information is presented with this report.

ABSTRACT OF REPLIES.

Moses Burpee, Chief Engineer, Bangor & Aroostook Railway: 1a. A box of one cubic yard capacity was used, with double leaf trap bottom, leaves hinged on opposite edges, making bottom of box "V" shaped at center, trap bottom tripped with tag line. The box, when filled, was covered with canvas fastened at four corners. b. On special occasions a tremie was used, but for general purposes the trap bottom box

was preferred. 2. Any depth. My experience about 15 ft. 3a. Perfectly satisfactory. 3b. Tremie method satisfactory. 5. Cost was not kept for comparative purposes. It would probably exceed ordinary concreting, not more than fifty cents per cubic yard.

F. L. Thompson, Engineer Bridges and Buildings, Illinois Central Railroad: 1a. Bottom dump buckets. The bucket was covered before placing under water, and the concrete dumped on the bottom of foundation. b. Telescope chutes extending through the water to the bottom of foundation. c. Depositing concrete in cloth sacks. 2. From 5 to 50 ft. 3a. Good results with proper handling. I consider this the best method. b. Good results with proper handling. c. Fair results, however not so good as by methods (a) and (b). 4a. Bucket should be lowered to within 2 ft. of the bottom, and then tripped, letting the contents deposit slowly, without moving the bucket. b. A continual stream of the concrete should be kept through the chute, the bottom of the chute being kept within a few inches of the foundation.

J. P. Snow, Consulting Engineer: 1a. Tremie. b. Bottom dump bucket. 2. Five to 30 ft. 3. Good in all cases. Bottom dump buckets so made that the concrete is enclosed in the bucket when the bottom opens, gives better results on small jobs than a tremie. The cost of installing a suitable traveler is too great on a small job to make a tremie pay. 4. To keep the stone from separating, and to keep the outside of the work solid with no voids, the tremie should be carried on a traveler capable of moving over any part of the work, and operations on a layer commence and finish in the interior of the work, so that the depositing will be continuous at the sides of the work. Layers should not be over 2 ft. thick.

T. W. Fatherson, Division Engineer, Chicago, Rock Island & Pacific Railway: 1a. Collapsible bucket with boom and hoisting engine for heavy work. b. Funnel and tube on light work when mixing is done by hand. 2a. Fourteen feet. b. Twelve feet. 4. Water should not be agitated by pumping while concrete is being deposited, else the cement will be washed out of the concrete.

Walter H. Norris, Bridge Engineer, Maine Central Railroad: 1. Wooden spout about 18 in. square. 2. Fifteen feet. 3. Good. 4. Keep the spout full of cement to exclude water and prevent wash. 5. About 50 cents per cubic yard more than by usual method.

E. H. Connor, Chief Engineer, Missouri Valley Bridge and Iron Company: 1. Bottom dump bucket. 2. Eight to 20 ft. 3. Good, hard cement. 4. Keep depositing continuously, until all the concrete is in position.

C. E. Smith, Superintendent, Sabine & Northern Railway: 1a. Tremie. b. Bottom dump bucket, orange peel or clam shell. 2. Twenty feet. 3. Hard uniform texture. 4. Very rich mixture, 1:2:3 very wet.

I. L. Simmons, Bridge Engineer, Rock Island Lines: 1. Bottom dump bucket. 2. About 10 ft. 3. Very satisfactory. 4. Lower the bucket as far as possible before depositing concrete, thus preventing the concrete from dropping through the water for any great depth.

C. H. Fake, Chief Engineer, Mississippi River & Bonne Terre Railway: We have filled cement or other sacks with concrete, tying mouth of sack with slip knot; lowered it into place and pulled string to untie knot, then withdrawn sack carefully. This serves the purpose fairly well on

small job. b. We have used spout on larger jobs, feeding the concrete slowly and carefully. 2. Two to 6 ft. 3. Presumed to be good. No examination has been made, but no settlement or movement has occurred. 4. Deposit with care and avoid haste.

J. M. Brown, Engineer Maintenance of Way, Chicago, Rock Island & Pacific Railway: 1. Eight years ago concrete was deposited under water, covering an area of about 40 ft. in length and 16 ft. in width. This was in a pit excavated in sand with cofferdam about same. The depth of the concrete was about 2 ft. It was a 1:2:4 mixture, the work being limestone crushed to about 1½ in. The depositing was done through a wooden box or tube about 12 in. square and about 25 ft. in length. This tube was suspended from a derrick, the boom of which swung over the entire area concreted. At the bottom of the tube was a slide which was opened after the tube was filled with concrete. The concrete was then fed into the tube continuously, while it was moved over the area. The tube was dropped to the bottom of the water, and gradually raised as the concrete was deposited. 2. About 11 or 12 ft. 3. Everything that could be desired. The concrete was deposited practically level. Water was pumped out after the concrete had been allowed to settle for about 10 days. 4. The mixture must be homogeneous, and deposited as quickly as possible after being mixed. Running water should be avoided.

Charles S. Churchill, Chief Engineer, Norfolk & Western Railway: 1a. Three years ago this company removed a concrete pier built in 1889 in about 20 ft. of water. This concrete was deposited in cast iron shell in which piles had already been driven. It was deposited by means of a telescope tube, the bottom of which was always kept close to the top of the concrete, as it flowed out of the tube into the water contained inside the cast iron shell. b. More recently a bottom dump bucket has been used, filled with concrete and lowered into place before the bottom was opened, the bottom being opened by a diver. The amount of concrete so placed was not great, because the object of placing it in this manner was to seal the bottom of cofferdam. After the cofferdam was sealed, the water was pumped out. 2a. About 25 ft. b. Thirty ft. of water. 3a. On removal the concrete was found to be in a very fair condition, although not so solid as it would have been, had it been deposited above water level. This was due to the fact that as thoroughly tamping could not be carried out, partly on account of being under water, and partly on account of the piles. b. On unwatering the cofferdam, the character of the concrete was found to be good. 4. We have found in all cases when concrete has been deposited in sea water, and has been allowed to set before making any additions, that there was on top surface of finished course of concrete a thin deposit, which was evidently a precipitate of the cement with sea water, and that it was necessary to remove this thin coating before any adhesion could be secured between any two layers of the concrete.

G. H. Scribner, Jr., Contracting Engineer: 1. When there are piles in the foundation, it is best to use two tubes, one being the larger, arranged so that it will slide up and down on the upper and smaller tube. I have also put grout into gravel bottom of 3 ft. in thickness by this same method. 2. This method can be used to a depth of 40 ft. 3. The pier of Manchac draw span for Illinois Central Railroad was put in in the above manner, an iron casing being used for pier with piles driven in foundation. Good results. Grouting gravel by same method satisfactory. 4. Tamp to prevent arching between piles. 5. Two outfits (four tubes), a one-half yard mixer was kept running to about one-half of its capacity.

Hans Ibsen, Bridge Engineer, Michigan Central Railroad: 1a. Tremie consisting of 12-in. square wooden pipe handled by hand power. b. Deposited by Lockwood Automatic concrete buckets. 2a. Tremie from 4 to 20 ft. b. Buckets 26 ft. 3b. In all cases concrete was found to have set well at the place where it was deposited by buckets. There was from 2 to 3 in. of soft sediment on top of hard concrete when water was pumped out, but concrete underneath this was in good condition. 4a. In using tremie, care must be taken to keep same full of concrete while the work is going on and in not lifting it too far from the bottom b. Bucket should be closed at top while being lowered through the water and care should be exercised that it is not raised too rapidly, so that the suction will retain the concrete in the bucket too long. 5a. The cost of depositing by tremie is probably about twice as much as by ordinary methods, due to the fact that concrete cannot be deposited in bulk, but has to be dumped on a platform and shoveled into the tremie. b. Depositing by buckets should cost very little more than depositing in the dry, when work is of such an extent as to require a plant for depositing by bucket method.

L. B. Martin, Engineer Maintenance of Way, Illinois Traction System: 1. Dry mixture was slowly dumped by wheelbarrows into the water until it had reached the surface of the water; then dumping was continued in same place and the accumulation worked down with a shovel until it had covered the whole excavation. 2. Two to 3 ft. 3. Very good. Concrete set up satisfactorily in 24 hours. 4. Mixture should not be dumped in such a manner as to separate the coarse aggregate from the cement and sand. It should not be thrown into the water with a shovel. It is a good idea to have the mixture very damp before it is deposited in water, as the coarse and fine aggregate will adhere to each other better in this way.

C. G. Delo, Engineer Maintenance of Way, Chicago Great Western Railroad: 1. Bottom dump buckets were lowered to the bottom, unlatched, and raised slowly. 2. Fifteen ft. 3. Some of the cement was removed and found to be first-class. 4. The unlatched bucket should be raised slowly to prevent wash. 5. Cost practically the same as when handled by ordinary derrick and bucket.

F. S. Stevens, Engineer Maintenance of Way, Philadelphia & Reading Railway: 1a. By means of a tube in still or enclosed water, the tube being raised slightly from time to time to allow concrete to escape from the bottom. b. I have also known of the use of paper bags. c. I have known of the use of burlap sacks. 2. Any depth in still water. 3a and b. Satisfactory results. c. Fairly satisfactory, but paper-bag method is probably better. The paper to be broken, and as much of it as possible withdrawn after concrete has reached its bed 4. The water must be enclosed to cut off current, and to prevent escape of cement.

W. H. Courtenay, Chief Engineer, Louisville & Nashville Railroad: 1a. A large number of piles in sea water were protected from attack by teredo by covering the submerged portions of piles with from 2 to 4 in. thickness of concrete. Forms were placed around the piles and then the concrete was deposited by pouring it through a tube. b. A bridge pier, built many years ago, was partially undercut by the river, and an attempt was made to fill the space vertically under the pier with concrete. The concrete was mixed moderately dry, and poured through an 8-in. wrought iron pipe from the track level. c For a bridge foundation recently constructed in 30 ft. of water, the cofferdam was first built of steel piles. Wooden bearing piles were then driven within the cofferdam

and cut off at the level of the river bed. The material around these piles was then excavated to a depth of about 4 ft. with centrifugal pumps, and then about 4 ft. of concrete deposited between heads of the piles by running it through iron pipes, the idea being to place 4 ft. depth of concrete around the piles before attempting to pump out the water from within the cofferdam, for, on account of the nature of the bottom, it was not feasible to pump the water out otherwise. 2a. Water ranged from about 18 ft. down. 3a. Successful. At times, however, mud at the bottom of the forms became mixed with concrete, greatly impairing the strength of the concrete. Upon examination by diver, some of this concrete was found to be good and some bad. 3b. During the progress of this work, the surface of the water within the cribs was at all times covered with a thick foamy scum. This work was constructed 20 years ago, and has given no trouble. 3c. After this concrete had been deposited and set, an effort was made to pump out the interior of the cofferdam, which was not successful. Examination by a diver disclosed the fact that the concrete in one spot of limited area was inferior in quality, and the water pressure was such as to create a blowout through this inferior concrete. The poor concrete was excavated by diver, and good concrete substituted, by lowering it in bags and having it placed by a diver, after which the water within the dam was pumped out, and the remainder of the pier constructed. 4. Although, as a general proposition, it would seem that concrete can be deposited under water at less cost than would be necessary for constructing water-tight cofferdams, and pumping the water out of the foundation before concrete is placed, the experience of the writer leads him to believe that it is generally unsatisfactory and should not be resorted to if foundations can be pumped out at reasonable cost.

E. I. Cantine, Contracting Engineer: 1. In 1891 it seemed impossible to lower the water for pier foundation as part of the construction of granite viaduct at Viaduct, Idaho, on the line of the Northern Pacific Railway. The usual cofferdam sheet-piling construction had been followed and an attempt was made to use the pumps to lower the water to the elevation of bottom of foundation; this seeming impossible, the concrete was deposited under water by use of circular pipe. This delivered the concrete at desired elevation below cut-off of piles. 3. Satisfactory. Foundations are standing and are in good condition. 4. There should be a continuous flow of concrete to reduce to a minimum separation of concrete beneath the water which tends to wash cement from the mixture.

H. T. Douglas, Jr., Chief Engineer, Wheeling & Lake Erie Railway: 1. We have had no experience except with cofferdams or caissons constructions. One of the most fruitful sources of disaster to poor concrete and which sometimes results in disaster to structure is the presence of flowing water in the foundations of concrete construction, carrying away the greater part, if not all, of the cement from the mixture. The best results that I have seen in the use of concrete under water was to mix the concrete, tie it up in bags and deposit these bags around on the outside of the foundations to give stability to the cofferdam and for the further purpose of lessening the amount of leakage. To place concrete in any foundation where water is in motion, in my judgment, would result, without doubt, in failure.

A. C. Everham, Assistant Chief Engineer, Kansas City Terminal Railway: 1a. At Detroit, Mich., in the construction of the Detroit River Tunnel, there was deposited about 100,000 cu. yds. of concrete through tremie pipes, the concrete being mixed upon a scow and poured in tremie, the lower end of which was always kept embedded in the soft concrete or in the mud at the bottom of the river. The concrete was

placed around the steel tubes which formed the waterproofing of the tunnel and was retained by cross partitions and a wooden form on the outside of the tubes, thus forming a "pocket" which permitted the concrete to set with minimum of disturbance. The mass of concrete for the enclosed tube was about 56 ft. wide at the top, about 32 ft. deep, and, when under water, about 40 ft. of water. On account of the pockets and lower end of the tremie pipe always being in soft cement, there was little, if any, disturbance of the cement in the concrete. 1b. In Toledo, Ohio, last year there was built by the C. H. & D. an ore dock of reinforced concrete, supported on piles, the lower 3½ ft. of which was deposited in water. Concrete was mixed on a scow and carried by pipe from hopper to point of deposit. The first few batches were deposited in the open water without protection, and possibly some of the cement was lost. 3a. The character of the concrete was ascertained as nearly as possible by taking samples with a calyx drill and obtaining a great many cores, from which several were selected at random and submitted to compression tests in the crushing machine. Of four cores taken thus at random, the concrete being a 1:3:6 mixture, there was found an average crushing strength of 3,239 lbs., the maximum being over 4,000 lbs. In order to compare this concrete with concrete placed under normal conditions in retaining walls, some cores were taken from a retaining wall at Detroit with same grade of concrete. Of four samples, the average was 2,320 lbs., as against 3,239 lbs. of the four samples deposited by tremie. 3b. On examination this concrete was shown to be of excellent quality.

E. D. Jackson, Assistant Engineer, Baltimore & Ohio Railroad: 1a. Bottom dump buckets, lowered to a little above the surface of concrete deposited before emptying. b. A spout of a size which can be conveniently raised or lowered, and the outlet moved to accommodate the discharge of concrete when required. 2. Five to 15 ft. 3. Masonry piers (concrete) in Mississippi River, which have proved successful construction, were on pile foundation; also piers in Rum River, near Anoka, Minn., Great Northern Railway. 4. Tight cofferdams should be used, as far as possible, to prevent any wash of current. Courses of an even thickness throughout should be maintained while depositing the concrete.

Lewis Kingman, Office Engineer, National Railways of Mexico: 1. In several cases we have used No. 10 centrifugal pumps, and have lowered the water as much as possible, then excavated 3 or 4 ft. below the water level. We used a 12-in. spout, with a hopper at top end. We kept the lower end of this spout practically embedded in concrete and the spout and hopper full of concrete. 2. Not over 4 ft. 3. O. K. 4. The deposit of concrete should be made without allowing the water to wash the cement out of the mixture.

H. L. Ripley, Engineer of Construction, New York, New Haven & Hartford Railroad: 1. Bottom dump buckets, preferably cylindrical, with height two or three times the diameter, bottom opening full size. Bucket should be lowered until same rests on bottom, latch released and bucket raised slowly to prevent concrete from separating. 2. Eighteen to 20 ft. maximum rise and fall of tide; outside of dam, 6 ft. 3. Twenty-four hours after depositing 10 ft. of concrete, the water was pumped out and a deposit of laitance averaging less than ½-in. was removed from the top of the concrete; after the surface was thoroughly cleaned, concreting was continued. The percentage of laitance will depend upon the care exercised in placing concrete. 4. Bucket should be lowered to the bottom carefully before latch is released. After bucket is opened, it should be raised slowly to deposit concrete directly on the bottom, thus preventing the material from separating. Concrete should not be disturbed

after it is deposited. 5. An ordinary ½-yd. Ransom mixer discharged into cylindrical buckets set on a lower platform; a derrick handled the buckets, which were unlatched by a jerk line. Cost no more than lowering concrete into ordinary open forms of equal depth.

Frank H. Alfred, General Superintendent, Cincinnati, Hamilton & Dayton Railway: 1. We have used a spout of 10-in. metal pipe, having at its top a hopper large enough to hold a batch. This spout and hopper we handled with a derrick, the hopper being filled. We raised the spout and hopper a small amount until the concrete ran out of the hopper, and not out of the spout proper, which was always kept filled with concrete. 2. Three to 20 ft. 3. A very good quality of concrete. 4. A rich mixture, about 1:2:4, should be used, and thoroughly mixed. Apparatus should be carefully manipulated to prevent concrete from running out of spout. Mixture should be rather stiff, and deposited in two layers. Care should be used alongside of forms; worked best from form toward center. Forms must be tight to prevent current.

E. B. Temple, Assistant Chief Engineer, Pennsylvania Railroad: 1. Last year there was successfully constructed a truss bridge across the Schuylkill River in connection with the Philadelphia Terminal improvements, where was deposited concrete under water for four piers of the bridge. The method pursued was as follows: A cofferdam of 12 in. by 12 in. timbers was built near the shore and sunk at low tide on the site of the pier. All possible excavating was done with a dredge previous to sinking the dam, and the rock foundation was cleaned as thoroughly as could be done by dredging. After the box, which, of course, was open at the bottom, was placed, a suction hose was used to remove material that could not be taken out by the dredge, or that drifted into the tide during the setting of the box. The bottom was also carefully examined by divers. Concrete was then deposited by means of a bottom dump bucket, with a cover on top. The bucket was lowered carefully to within 2 ft. of the bottom, and after resting a moment the bottom was released and the concrete gradually settled into place. The top of the concrete was kept as level as possible by having the buckets dumped uniformly over the entire surface. This concrete was carried up to within 2 ft. of low water and allowed to set for at least a week before the cut-stone piers were started. 1b. A bridge was constructed, in 1902, over the Schuylkill River in about the same depth of water as the one above referred to, by the usual method of pumping out the dam, so that the concrete could be deposited in the open air all the way down to the rock. Several months were consumed in the attempt, and finally from about 6 to 8 ft. of the foundation had to be constructed under water, as it was impossible to keep the dam tight at the bottom and pump out all of the water. 2. The water in the deepest pier was 40 ft., and no trouble whatever was experienced in this method of construction. 5. The cost of a plant for depositing the concrete in this way would practically be the same as for depositing it in the open air. The stone and sand were brought to the site on scows, and the concrete mixer and derricks were also on floating equipment. With such a plant, and following the usual method of pumping out the cofferdams before depositing the concrete under water, the cost would be about $25 per cu. yd. By depositing the concrete, as done in this case, the cost averaged about $21 per cu. yd. These, apparently, high prices include excavation or dredging, cofferdams and all cost in connection with the operation.

R. N. Begien, Assistant to General Manager, Baltimore & Ohio Railroad: 1a. In still water less than 12 ft., after solid foundation is secured and made level, concrete should be mixed 2 sand and 4 stone,

stiff enough to bear a man immediately after being mixed. This should then be lowered to the bottom of water in round drop-bottom buckets. holding from one-half to three-quarters of a cubic yard. The concrete so placed should be kept reasonably level over the entire surface. If the water is of greater depth than 12 ft., a diver should be employed. After concrete is deposited, it should not be disturbed any more than possible. b. Concrete to be deposited under running water should be placed in cloth sacks filled two-thirds full and sewed at the extreme top, and lowered in drop-bottom bucket or scale box. By using care a good level and solid mass can be obtained, and foundation put in any reasonable depth of water. 3. We have known of concrete to be put in in this way, and have never heard of any failure. 4. Careful workmanship, absolutely no haste, thorough supervision of each man, as well as using the best of materials. The work should be carried on as continuously as possible. 5. The same plant necessary for putting in cofferdam work, where water has been pumped out, will install concrete in water. In my opinion, such a plant would cost approximately $2,000. Where concrete can be put in foundation for $6 per cu. yd., it would cost in still water about $7.50 per cu. yd. In running water, where cloth sacks are used, the cost would be about $9.50 per cu. yd.

F. W. Gilcreast, Chief Engineer, Lehigh & New England Railway: 1. All pumping of water should be stopped and concrete deposited by means of a spout, the bottom of which being 2 or 3 in. above the level of the concrete and moved about slowly. Care should be taken to keep the spout full of concrete. 2. Ten to 15 ft. 3. Good. 4. Foundation must be enclosed to stop all flow of water Concrete should be mixed as dry as possible and spread evenly over foundation in layers about 6 in. at a time.

W. C. Smith, Chief Engineer of Maintenance of Way, Northern Pacific Railway: 1. Bottom dump bucket of 2-yd. capacity. no top cover. A tremie in some cases. Usually deposited in a crib sunk by open excavation or for sealing the bottom of a cofferdam where character of bottom is such that dam cannot be pumped out. 2. Thirty to 45 ft. 3. Satisfactory in all instances observed. In all cases where cribs have been pumped out after footing has been deposited through the water, concrete has been found to be sound and as well set up as material deposited in open air. 4. Concrete should be deposited continuously and carried in even layers across the bottom of the excavation in order to prevent the formation of pockets of laitance. It is very important that there be no interruption in depositing concrete through the water after same has once been begun. Cribs or cofferdams must be tight and no flow of enclosed water permitted. Bucket must be down on same mass when dumped, and care used in withdrawing bucket to prevent lifting and dropping the load through the water. 5. It is but little more expensive to deposit concrete through the water by means of a bucket than to deposit with a bucket in open excavation.

George H. Bremner, Engineer, Illinois District, Chicago, Burlington & Quincy Railroad: 1. Caissons filled with dry mixture of concrete and water. Bottom dump buckets, lowered windlass, were used for depositing. 2. About 50 ft. 3. Water was pumped out the following day and concrete was in good condition.

Joseph O. Osgood, Chief Engineer, Central Railroad of New Jersey: 1a. In long, narrow walls the operation has been commenced at one end and concrete deposited in bottom dump buckets until the concrete showed above the level of the water, from which point an ordinary bucket

was used and the concrete deposited on top of portion showing above water, gradually forcing the concrete below water toward opposite end from which the operation was commenced. The level of the concrete was kept nearly on a plane with the level of the water, by which means the setting of the concrete was slow, and the mass was forced gradually forward without having the concrete roll down the side. The water beyond the concrete remained clear during the whole of the operation. b. Bottom dump bucket, with lid or cover over the top. 2a. Three to ten feet. The operation was commenced at the 3-ft. end. b. About 10 ft. 3. Very good 4. The flow of the water must be cut off in such a way that there will be no current in the area in which the wall is to be constructed. b. Bucket must be so constructed that there will be no rush of water through it and the concrete while being lowered. 5. Cost no greater than for depositing by usual methods above water. Building dam to cut off the current is an added expense.

John D. Isaacs, Consulting Engineer, Harriman Lines: 1a. Bottom dump bucket lowered slowly through the water and dumped when resting on the bottom. b. Tremie, handled by means of a winch, derrick or chain hoist, and moved to any desired position by means of a trolley way. c. Concrete blocks, molded and permitted to become thoroughly set in open air. 2a. Twenty-two to 55 ft. b. Six to 135 ft. 3a. Good in all cases. Probably better results can be attained by this method than by the use of a tremie. In one instance work was discontinued for several months, and the surface of the concrete in the form at this time being about 8 ft. below the surface of the water. Examination showed that the upper surface of the concrete had taken a very hard permanent set, and that the character thereof was fully as good as concrete placed above water. In the structure herein referred to, about 4,000 cu. yds. of concrete, included in piers below water, was handled by method above described. b. Generally good, but in cases of deep foundations where tremie had to be lifted to clear bracing of cofferdam and tops of piles, it is possible that the results are not so good as though the operation were carried on continuously, since the charge in the tremie drops and the recharging has to be done through the water in the tube. c. Good. This method is especially adapted to locations where it is impossible to avoid current in the water. 4. There should be practically no current in the water. Bottom dump method. The bucket should rest upon the foundation before the concrete is dumped. Bucket should be raised and lowered so as to cause least disturbance of water possible. Tremie method. The concrete should be permitted to run out at the discharge end as fast as it is deposited in hopper end. Concrete should be distributed in as even layers as possible. Laitance or other inert materials which may have accumulated by reason of discontinuance of operations should be cleaned off before additional concrete is deposited. The amount of cement in the mixture should be slightly over that used for depositing the dry in order to offset any loss which may occur by wash. 5. The relative cost depends much upon the depth of water through which the concrete is deposited. Cost data kept for constructive work on the Oregon-Washington Railroad & Navigation Company indicate a cost of approximately $1.00 per cu. yd. for depositing with bottom-dump bucket when it would cost 75 cents per cu. yd. in the dry. Under similar conditions the cost with the tremie was about $1.40 per cu. yd.

R. Budd, Chief Engineer, Spokane, Portland & Seattle Railway: 1a. Bottom-dump bucket, having single leaf, about ¾-yd. capacity b. Tremie consisting of steel pipe of about 24 in. diameter choked down to 12 in. at lower end. c. Two wooden tremies of same diameter throughout entire length. 2a. Six ft. b. Fifteen ft. c. Twelve ft. 3a. Successful. b. As

concrete would not flow freely, bottom-dump bucket was substituted. c. Successful. Charges were very seldom lost, and when this did happen, an extra quantity of cement was used in refilling the tube. 4a. Bucket should be of large capacity, and should be handled slowly under water. Bucket should rest on bottom before it is dumped. Bottom constructed with two leaves is better than with one, as it causes less disturbance of the water. c. Tremies should be handled very slowly to avoid disturbance of the water. Avoid losing charge. Tube should be of same diameter throughout, and it is well to have hopper at upper end.

M. J. Caples, Vice-President, Chesapeake & Ohio Railway: 1. Concrete was placed in loosely woven gunny sacks and dropped through the water into position. The concrete in bags was leveled with long poles as the work began. 2. Six ft. 3. This work was done twenty-one years ago, when concrete was used much less than it is to-day. The object in view in depositing this concrete was to even up the foundation for a bridge abutment. The foundation was limestone rock, as I recall it, about 50 cu. yds. of concrete being used in this way. The abutment built upon this foundation is still in excellent condition.

F. L. Wheaton, Engineer of Construction, Delaware, Lackawanna & Western Railroad: 1a. Bottom-dump bucket with lid, first landed on bottom of foundation, after the water had become still, was carefully raised, leaving the concrete upon the bottom. b. Movable chute. Chute should be filled with concrete to a point above the water line, raised and moved with a derrick, allowing concrete to flow out the bottom as fast as it is deposited on top. 3. Very satisfactory. 4. The concrete should be mixed much drier for use under water than for use above, as in this way there is less danger of the cement washing out of the aggregate. 5a and b. The cost of depositing concrete by these methods is only slightly more than if water were pumped out.

Lincoln Bush, Consulting Engineer: 1. I have used steel buckets for this purpose, with opening at the bottom. The buckets were lowered to full depth before the concrete was deposited. 2. About 15 ft. 3. Very satisfactory. 4. Buckets should be tight, to prevent flow of water through the concrete in lowering, lowered full depth before concrete is deposited. Before the day's work is started, the inert deposit on top of concrete which has accumulated from previous day's work should be pumped off. This can be done by lowering suction pipe down on the concrete, and moving the suction about over entire area, the concrete of previous day's work having set sufficiently to prevent the removal of the cement by pumping.

A. J. Himes, Engineer Grade Elimination, New York, Chicago & St. Louis Railroad: 1a. Concerning the deposition of concrete under water, my experience has been confined to comparatively shallow depths. I have used a rough wooden box as a substitute for a tremie. b. I have permitted concrete to slide gently into the water through chutes, first forming a pile of concrete in form of cone, and permitting it to raise to the surface of the water, then, as further concrete is deposited, the mass is permitted to extend horizontally under its own weight. This method gives very good results. c. I have placed concrete under water in gunny sacks. The use of the sacks was, of course, a simple device to prevent the washing of the concrete. d. I have inspected the deposition of concrete 50 ft. below water surface under compressed air, where air pressure was allowed to decrease as the surface of concrete rose, so that the water surface was maintained at approximately the surface of the concrete. 2a and b. Comparatively shallow. d. Eighty feet. 3a. Very good results. b. Very good results. d. Wholly successful for depths

as great as 80 ft. 4. The concrete should be mixed rather wet, and all agitation thereof should be avoided after it has been placed in the water. Workmen generally seem determined to stir up the concrete and shovel it around beneath the water, and it is oftentimes hard to overcome this disposition. The only precaution necessary is to insure that the surging or washing of the water does not wash the cement from the aggregate. Any method which will prevent this condition will be successful, in so far as the proper hardening and durability of the concrete is concerned.

**Job Tuthill, Assistant Engineer, Kansas City Terminal Railway:* 1a. Filled 8 ft. in bottom of a circular sheet pile crib with a cubical box having bottom in halves, hinged to the sides. Box closed and handled with load by one rope, and placed where concrete was wanted, then box dumped by second rope similar to the way orange peel buckets are handled, and pulled in. 2. Fourteen feet. 3. Very satisfactory. The concrete was nearly level and spread out against sides of crib when pumped out. 4. Handle carefully. After the steel tubes forming the river section of the La Salle Street Tunnel under Chicago River, Chicago, Ill., had been sunk in place, it was necessary to construct a cofferdam at each end of the tubes, behind which the water could be pumped out, permitting connections to be made to the land sections. At each end of the river section there was a timber crib 11 ft. wide, securely fastened to the tubes and reaching 3 ft. above the surface of the river. From the ends of these cribs pockets, approximately 17½ ft. square, were formed by driving Friestedt steel sheeting of from 50 to 65 ft. in length. Within these pockets the depth of water ranged from 45 to 53 ft. On account of this extreme depth, it was not deemed advisable to fill the pockets entirely with clay, but to fill the bottom with concrete to a depth below water level of about 37 ft., and in the same operation fill the space between the shell of the tubes and the bottom of the excavation. Reference to the accompanying sketch will give a clear idea of the construction of the cribs, pockets, etc. An attempt was made to deposit concrete by the tremie method, by use of a 12-in. diameter pipe and permitting the concrete to spread from the bottom end of the pipe. This method did not prove successful on account of the difficulty of keeping tremie full of concrete, and the difficulty of manipulating the same in this depth of water. An examination by diver indicated a considerable segregation of the sand and stone to the extent that this method was abandoned.

The following method was then determined upon: Gas pipes, 1½ in. diameter, were bent to the radius of the tunnel tubes and placed so that they would discharge at varying distances underneath the tubes. Four of these pipes were placed in each pocket and rigidly fastened in position by submarine divers. As indicated on accompanying sketch, these pipes did not have well points attached to the ends. In addition to the bent pipes, each pocket contained twelve to fifteen 2-in. diameter pipes, equipped with well points, stripped of the netting, at bottom ends, and placed so as to be about 2 ft. above the bottom of the excavation. The top end of all pipes was threaded for attachment to the grouting machine. About 5 ft. of broken stone was then spread over the bottom of the pocket and grout under a pressure varying from 35 to 100 lbs. per sq. in. was then forced through the pipes to fill the voids in the layer of stone.

In general, the grout consisted of a mixture of about five bags of cement to one barrow of torpedo sand. All lumps, gravel, etc., which would clog the well points, were removed from the cement and sand before mixing. The grout was thoroughly mixed before being put into the McMichael's compressed air mixer. After placing the bottom course as above, a second set of pipes and another layer of broken stone were

*Acknowledgment is made of valuable information furnished by the engineers of the La Salle Street Tunnel, Chicago, for use in this abstract.

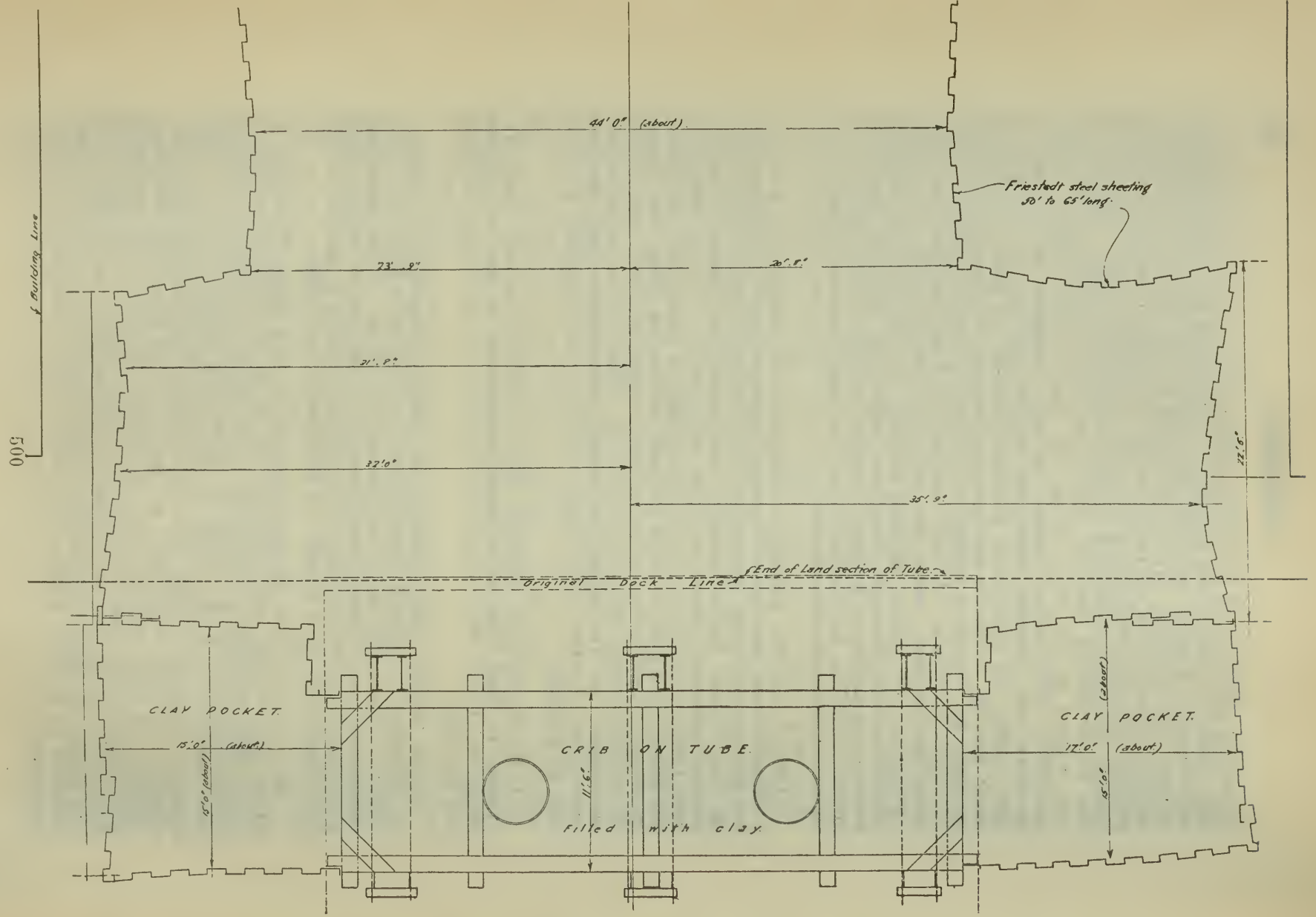
placed and grouted as before. This process was continued until the desired height of concrete was obtained. This method made use of quite a large number of pipes, as it was impossible to remove them after the grouting was complete. The method used in the south cofferdam was similar to that used in the north, except that in the main section of the pockets, only one set of pipes was used. After these had been put in position, the whole volume of broken stone was deposited. Grout was then forced through the pipes, and as the grouting continued, the pipes were worked up and down through the mass of stone until the voids were filled. This method appeared to be as successful as that used in the north dam, although about three hundred bags less of cement were used. During the operation of grouting, whenever the grout was flowing freely into the voids, the pressure was from 40 to 50 lbs. per sq. in., but when the voids were practically filled, this pressure became 90 to 100 lbs. The operation at all times continued until no more grout could be forced into the pipes. After the concrete had sufficiently set, the remaining volume of the pockets was filled with clay; the north dam proved in all respects securely watertight, leaks were slight, and the water apparently flowed along the line of separation between the clay and the concrete. In the south dam, one bad leak developed, the water apparently coming from the river underneath the concrete.

John R. Leighty, Engineer Maintenance, Missouri Pacific Railway: 1. Wood forms were made from 3 x 6 piers and set on solid rock bottom of river; concrete lowered into form in steel buckets with swinging drop bottom; bottom unlatched and bucket lifted, allowing concrete to drop to bottom of form. 2. Two to six feet. 3. Three small piers were built up to about 1 ft. above surface of water, and false work was placed upon them to carry the ends of the two double-track spans, 175 ft. each, under traffic of one hundred trains per day. After use of about three months, they were abandoned. They did the work without any trouble. 4. The forms were built of rough lumber and were not water tight. Buckets were lifted carefully, so as to agitate water as little as possible.

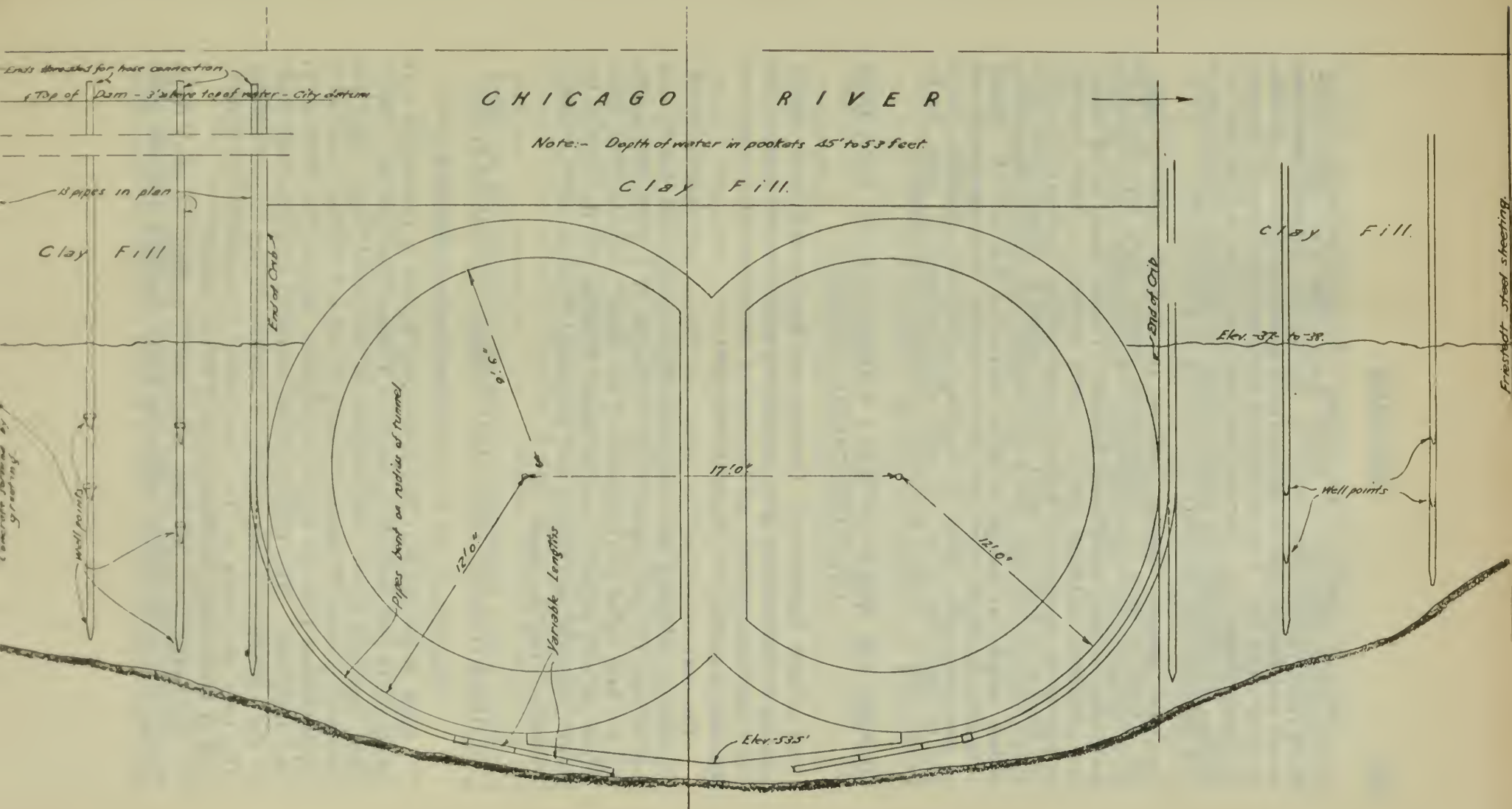
J. R. W. Ambrose, Engineer Grade Separation, Grand Trunk Ry. System: 1. Box chute with funnel arrangement on top. 2. Six to 10 ft. 3. Good where water remains quiet. 4. Box must be filled and kept filled.

C. D. Purdon, Chief Engineer, St. Louis & Southwestern Railway: 1a. Tremie. b. Bottom-dump bucket. 3. Appear to have been satisfactory, as no trouble has been experienced with any of the foundation so deposited. 4a. Tremie should be kept full and deposit made in small quantities. b. Bucket should touch bottom before it is opened, so that the concrete may pass through as little water as possible.

W. A. Clark, Chief Engineer, Duluth & Iron Range Railroad: 1. About 6,000 cu. yds. were deposited by means of bottom-dump bucket in ore dock foundation. Trial with tremie in this case did not seem to secure equally as good results. 2. Four and one-half feet. 3. Drill cores were not secured, so that results were not absolutely known, but samples deposited in same way and afterwards removed and examined, showed very little separation. 4. Bucket should have large discharge opening and have canvas cover, to decrease washing and consequent separation. In this case water was at a temperature of 32 degrees and 28 degrees Fahrenheit, and so retarded the setting of the cement that there was danger of slight wave action causing separation, so it was thought necessary to heat the water with a steam jet to a temperature of 45 to 50 degrees.



TUBES AND COFFERDAM, LA SALLE STREET TUNNEL, CHICAGO, SHOWING METHOD OF GROUTING CRUSHED STONE.



TUBES AND COFFERDAM, LA SALLE STREET TUNNEL, CHICAGO, SHOWING METHOD OF GROUTING CRUSHED STONE.

George W. Boschke, Chief Engineer, Oregon-Washington Railroad & Navigation Company: 1. Bottom dump bucket with single line. 2. From 110 to 135 ft. 3. First-class. 4. The material should be distributed evenly and buckets covered before reaching bottom, which can be done by using single line. This arrangement is patented by George T. Forsyth, Portland, Oregon. 5. Derricks were used, the same as those used on shore. The only difference in cost of plant is additional length of cables and additional time necessary for lowering to greater depth.

Robert Armour, Masonry Engineer, Grand Trunk Railway System: 1a. Tremie or spout. b. Bottom-dump bucket. Both have been used to a limited extent only; both good. Bottom-dump bucket generally preferable as being more easily handled. Bucket should be of largest size practicable, and have cover. 2. Five to 8 ft. 3. There has been no subsequent examination by diver or unwatering, but concrete set well, and there is no failure to report. Either method is, without doubt, satisfactory, if used with care. 4. A slow, regular movement of tremie, with bottom raised just enough to allow concrete to flow out. b. Bucket should be discharged when it is close to bottom. Rich concrete should be used, thoroughly mixed, of "quaking" consistency. Materials should not be used dry, as air in voids when displaced by water carries cement with it. Disturb it as little as possible after placing it.

REPORT ON WORK OF JOINT COMMITTEE ON CONCRETE AND REINFORCED CONCRETE.

The Joint Committee on Concrete and Reinforced Concrete held a meeting at Atlantic City, June 30, 1911, at which time the work of the Committee was gone over and the previous record carefully studied, with the view of putting it in shape for final report.

The work of revising the report was allotted to a number of subcommittees. Although these committees have reported back and the data put in shape to again present to the Committee as a whole, the meeting has not been called for ratification of the report; therefore, your Committee can only present a progress report, believing that the work of the Joint Committee on Concrete and Reinforced Concrete will be finished sometime during the present year.

UNIFICATION OF PORTLAND CEMENT SPECIFICATIONS.

(Specifications for Natural Cement were not considered.)

Early in the year 1911 two Government Boards or Committees were appointed to deal with the question of Cement Specifications. One of these, appointed by the Chief Engineer of the United States Army, was instructed to revise Professional Papers No. 28; the other was made up of representatives from the various departments, appointed by the head of each department. This Committee was instructed to prepare and report to the departments a single Standard Specification for the Government. This body was known as "The Departmental Committee for the Unification of Government Specifications for Portland Cement."

On September 12 the Army Board held a meeting at which representatives from the various engineering bodies interested in cement speci-

cations, from the Association of American Portland Cement Manufacturers and representatives from one or two commercial laboratories, were in attendance. At this meeting the Army Board received suggestions for the revision of Professional Papers No. 28.

Following this meeting the Departmental Committee issued a tentative specification, which was sent out with request for criticism and suggestion.

On November 24 a meeting was held at Washington which was attended by representatives from the Departmental Committee, the Army Board and the American Railway Engineering Association. Committee C-1, American Society for Testing Materials, and Committee on Uniform Tests for Cement, American Society of Civil Engineers, were not represented, though they had previously accepted the invitation to be present. It was apparent that the tendency of the Departmental Committee was to adhere quite closely to the standard adopted by the American Society for Testing Materials, which is also the standard of this Association.

On November 27 a meeting was held in Philadelphia, attended by representatives from the Committee on Uniform Tests for Cement, American Society of Civil Engineers, Standard Specifications for Portland Cement (C-1), American Society for Testing Materials, and through its membership on Committee C-1 this Association was represented. The Association of American Portland Cement Manufacturers and the Departmental Committee were also represented. The principal question before this meeting was that of Uniform Methods, and an agreement was reached on every point excepting the use of the Vicat Needle vs. Gilmore Needle in determining time of set, and Vicat Needle vs. Ball Test in determining normal consistency.

On January 8, 1912, representatives from the Departmental Committee and Committee on Uniform Tests for Cement of the American Society of Civil Engineers met with the Army Board to further consider the points of difference in the respective specifications. Agreement had been reached upon all points excepting those previously mentioned, and at this meeting the representatives of the American Society of Civil Engineers expressed preference for retaining the Vicat Needle, but offered to compromise and accept the Ball Method as the means of determining normal consistency if the Government representatives would accept the Vicat Needle as the method of determining the time of set.

After due consideration the Government representatives were convinced that the Gilmore Needle should be retained in their specifications; also, that the Ball Test for determining normal consistency is preferable to the Vicat Needle, and a specification which agrees with the standard of this Association in other particulars was approved by the Departmental Committee and the Board of Engineer Officers and recommended for adoption as a United States Government Standard Specification for Portland Cement.

The Committee on Uniform Tests for Cement, upon making their report to the American Society of Civil Engineers in January, stated that they had been unable to get together with the Army Board and the Departmental Committee on Methods of Tests, and, considering their work

finished, asked to be dismissed. The Committee was accordingly relieved from further duty.

CONCLUSIONS.

Your Committee recommends the adoption of the following conclusions:

(1) That the conclusions in reference to Methods of Patching and Repairing Plain and Reinforced Concrete be approved as good practice.

(2) That the conclusions in reference to Methods of Depositing Concrete Under Water be approved as good practice.

Respectfully submitted,

COMMITTEE ON MASONRY.

REPORT OF COMMITTEE XI—ON RECORDS AND ACCOUNTS.

H. J. Pfeifer, *Chairman;*
J. M. Brown.
Edw. Gray.
E. E. Hanna.
Henry Lehn.
J. H. Milburn.
C. W. Pifer.
M. C. Byers, *Vice-Chairman;*
Guy Scott.
W. A. Christian.
G. J. Graves.
C. W. Cochran.
G. T. Warren.
H. Stephens.

Committee.

To the Members of American Railway Engineering Association:

Your Committee on Records and Accounts respectfully submits herewith its report:

The Board of Direction assigned the following work to your Committee for the current year:

(1) Make a comprehensive study of the forms in the Manual which were adopted a number of years ago.

(2) Study the economical way of managing a storehouse so as to assure a minimum stock of materials at all times.

(3) Make concise recommendations for next year's work.

The following Sub-Committees were appointed:

Sub-Committee A—Study of Forms in Manual: C. W. Cochran, Henry Lehn, J. H. Milburn, Guy Scott, H. Stephens, G. T. Warren.

Sub-Committee B—Economical Storehouse Management: J. M. Brown, W. A. Christian, G. J. Graves, Edw. Gray, E. E. Hanna, C. W. Pifer.

EXPLANATORY STATEMENT.

Two meetings were held during the year; one of Sub-Committee B at St. Louis on October 23, 1911, attended by Messrs. Brown, Byers and Pfeifer, and another of the entire Committee at Chicago on November 28, 1911, attended by Messrs. Byers, Brown, Christian, Graves, Milburn and Pfeifer.

The Committee devoted by far the greatest part of its time to subject (2), the first point discussed relating to the scope of the instructions as follows: Should the internal economy of the storehouse be solely considered, or should the effects of storehouse management on the broader economies of maintenance and operation be also taken into consideration. As the first involves a storekeeping rather than a maintenance or operating problem, the Committee decided to base its investigation and report on the second interpretation.

Material and labor are required in the construction, maintenance and operation of railroads; and since it is impossible to secure materials when, and in the quantities required, by direct purchase, a reserve stock is accumulated which is drawn upon to meet the demands as they arise.

The following figures are taken from the report of the Interstate Commerce Commission for the year ending June 30, 1909:

Operating expenses of the railroads of the United States for the year ending June 30, 1909, amounted to $1,599,443,410 (p. 75).

Machinists, carpenters, other shopmen, section foremen, other trackmen, other employes and laborers, whose efficiency depends to a great extent on their having proper materials and tools, received in wages $466,138,215, or about 29 per cent. (p. 46) of the entire operating expenses.

The general balance sheet for the same period gives the value of materials and supplies on hand at $206,849,619 (p. 82). Five per cent. per annum on this sum is $10,342,481, about 2.2 per cent. of what was paid during the year to the classes of employes above mentioned.

Assuming that it is possible to reduce the stock on hand to the extent of 50 per cent., the saving per annum would be only 1.1 per cent. of the amount paid annually in wages to the above mentioned employes, so that even a slight loss in their efficiency through failure to secure materials and tools as required, will soon absorb much more than the amount saved by reduced investment in stock. It would seem, therefore, that the most important function of a storehouse is the prompt delivery of materials and tools so that delays to labor resulting from their lack may be reduced to a minimum.

CONCLUSIONS.

It is recommended—

(1) That no changes be made in the forms appearing in the Manual.

(2) That the following statement embodies the general principles governing the economical management of a railway storehouse:

REASONS FOR MAINTAINING A STOREHOUSE.

The object of a storehouse is to provide material and tools when required so that the cost of work may be a minimum, bearing in mind the factors of delay to work or labor, also interest on investment in stock.

The following essential elements enter into the problem:

(a) STANDARDIZATION.—The standardization of materials and instructions in regard to their use will reduce to a minimum the number of items of material of the various classes which should be carried in stock. The amount of each item which should be carried in stock will depend upon the rate of consumption, time required for the purchase and delivery of material, and also upon local conditions.

(b) CLASSIFICATION OF MATERIAL.—This is necessary so as to reduce to a minimum the cost and time of handling. An approved classification should be followed in making requisitions.

(c) STOCK ACCOUNT.—An account should be kept of stock showing at all times a record of receipts, disbursements and amount on hand.

Stock should be replenished when the amount of any item has been reduced to a fixed minimum. Inventories should be made at stated periods. A proper stock account furnishes a check on excessive supply and obsolete material.

(d) DISTRIBUTION.—When material is shipped, notice should be sent to consignee showing partial or complete filling of requisition and if partial, when final shipment may be expected.

(e) ORGANIZATION.—The storekeeper's place in the general organization should be so fixed and adjusted that the measure of his efficiency is primarily, the promptness and accuracy with which he fills requisitions, and, secondly, his ability to hold down the stock investment to the lowest amount consistent with the first requirement.

Respectfully submitted,

COMMITTEE ON RECORDS AND ACCOUNTS.

REPORT OF COMMITTEE XVI—ON ELECTRICITY.

GEORGE W. KITTREDGE, *Chairman;*	J. B. AUSTIN, JR., *Vice-Chairman*
R. D. COOMBS.	C. E. LINDSAY.
A. O. CUNNINGHAM.	W. S. MURRAY.
L. C. FRITCH.	J. R. SAVAGE.
GEORGE GIBBS.	W. I. TRENCH.
G. A. HARWOOD.	H. U. WALLACE.
E. B. KATTE.	*Committee.*

To the Members of the American Railway Engineering Association:

Your Committee presents herewith its second annual report, its first annual report appearing in Vol. 12, Part 1, of the Proceedings of the Association for the year 1911, which report contains the History and Bibliography.

The Association directed that the outline of Committee work for the year 1911 be as follows:

(1) Continue the consideration of the subject of Clearances.

(2) Continue the preparation of Standard Specifications for Overhead Transmission Line Crossings.

(3) Report on effect of electrolytic action on metallic structures and best means of preventing it.

(4) Method of insulation and protection.

In accordance with the instructions of the Board of Direction, that two subjects would be the maximum for the action of the convention, your Committee has confined itself to the following subjects:

(1) Clearances.

(2) Transmission Lines and Crossings.

Two meetings have been held in New York, one on August 7, 1911, at which were present Messrs. Kittredge, Coombs, H. A. Currie (representing Mr. Katte), Harwood, Lindsay and Savage, and at New York on January 29, 1912, at which were present Messrs. Kittredge, Austin, Coombs, Fritch, Gibbs, Harwood, Katte, Lindsay and Trench.

The balance of the work of the Committee has been done by correspondence and by the chairmen of the Sub-Committees on "Clearances" and "Transmission Lines and Crossings," Messrs. Harwood and Coombs, respectively.

CLEARANCES.

At the last meeting of the Association at which our report was considered it was decided that in view of the fact that the American Railway Association had a Committee on Clearance Lines and the American Electric Railway Engineering Association also had a Committee on Clearance Lines, and because of the fact that the Committee on Electricity had not been able for various and sundry reasons to reach conclusions with them and agree upon lines satisfactory to all concerned, to accept the report on clearance as one of progress only, with the idea of prior to the next meeting agreeing with the other associations mentioned upon lines that would be satisfactory to all.

The chairman of the Sub-Committee on Clearances has subsequently been in communication with representatives of the committees of the other two associations mentioned with the result that the diagram "A," shown on page 525, is now submitted as the recommended clearance lines for equipment and permanent way structures adjacent to third rail and for third rail structures.

It is believed that similar diagrams will be recommended to the American Railway Association by the Committee on Electric Working and by the Committee considering the subject of Clearance of the American Electric Railway Engineering Association.

Diagrams have been obtained from all the principal railways in the United States using third rail showing outlines of their third rail structures and from some of the principal steam railroads diagrams showing outlines of maximum equipment. These various diagrams are made a part of this report and were used as a basis in establishing clearance lines for third rail structures, permanent way structures adjacent to third rail and equipment.

On page 524 there also appears a table showing "Data regarding Third Rail Clearances," which is made a part of this report and which has been prepared from information recently received from various companies with a view of ascertaining what proportion of track mileage, of roads using both steam and electricity, will clear the recommended clearance lines.

From an inspection of this table it will be noted that out of a total mileage of 1,988.04 using steam and electricity, 973.80 miles will clear. It will also be noted that the mileage not clearing is mainly interurban electric roads which handle steam equipment as secondary traffic and elevated roads in cities which do not handle steam equipment.

At the last meeting of the Association the definition for "Third Rail Gage" as follows was adopted:

"Distance, measured parallel to plane of top of both running rails, between gage of running rail and center line of third rail."

It is now proposed changing the definition to read as follows:

"Third Rail Gage.—Distance measured parallel to plane of top of both running rails between gage of nearest running rail and inside gage line of third rail."

TRANSMISSION LINES AND CROSSINGS.

The Sub-Committee Chairman, Mr. Coombs, has been working in conjunction with Committees of the National Electric Light Association, American Institute of Electrical Engineers, American Electric Railway Association, Association of Railway Telegraph Superintendents, and representatives of the telephone and telegraph companies, in connection with the preparation of specifications for overhead crossings of electric light and power lines, and the following specification is submitted which is identical with the specific tions that have been adopted by the other associations mentioned, excepting in paragraphs Nos. 10, 13, 18, 24, 29, 31, 32, 34, 45, 49, 51, 55, 60 and 61, which changes it will be noted by comparing the specifications are in line with more clearly expressing the condition or of making them more satisfactory from the point of view of the railroads.

For the convenience of the members the paragraphs mentioned are given as Appendix "B" to this report in the form in which they have been adopted by the other associations mentioned above.

RECOMMENDATIONS.

(A) The Committee recommends for adoption by the Association:

(1) Definition: "Third Rail Gage.—Distance measured parallel to plane of top of both running rails between gage of nearest running rail and inside gage line of third rail."

(2) The lines shown on diagram "A" as equipment clearance lines.

(3) The lines shown on diagram "A" as permanent way structure adjacent to third rail clearance lines.

(4) The lines shown on diagram "A" as third rail structure clearance lines.

(5) The adoption of the Specifications for Overhead Crossings of Electric Light and Power Lines.

(B) The Committee recommends a continuation of work already outlined, particularly consideration of clearance for overhead third rail working conductors, electrolysis and insulation and the consideration of any new information that may develop in reference to maintenance organization and relation of track structures, and asks for such other direction or instructions as seem necessary or desirable.

Respectfully submitted for the Committee,

GEORGE W. KITTREDGE,

Chairman.

Appendix A.

*SPECIFICATIONS FOR OVERHEAD CROSSINGS OF ELECTRIC LIGHT AND POWER LINES.

GENERAL REQUIREMENTS.

Scope.

1. These specifications shall apply to overhead electric light and power line crossings (except trolley contact wires), over railroad right-of-way, tracks, or lines of wires; and, further, these specifications shall apply to overhead electric light and power wires of over 5,000 volts constant potential, crossing, or constructed over telephone, telegraph or other similar lines.

Location.

2. The poles, or towers, supporting the crossing span preferably shall be outside the railroad company's right-of-way.

3. Unusually long crossing spans shall be avoided wherever practicable.

4. The poles, or towers. shall be located as far as practicable from inflammable material or structures.

5. The poles, or towers, supporting the crossing span, and the adjoining span on each side, preferably shall be in a straight line.

6. The wires, or cables, shall cross over telegraph, telephone and similar wires wherever practicable.

7. Cradles, or overhead bridges, shall not be used.

Clearance.

8. The side clearance shall be not less than 12 ft. from the nearest rail of main-line track, nor less than 6 ft. from the nearest rail of sidings. At loading sidings sufficient space shall be left for a driveway.

9. The clear headroom shall be not less than 30 ft. above the top of rail under the most unfavorable condition of temperature and loading. For constant potential, direct-current circuits, not exceeding 750 volts, when paralleled by trolley contact wires, the clear headroom need not exceed 25 ft.

10. The clearance of alternating-current circuits above any existing wires, under the most unfavorable condition of temperature and loading, shall be not less than 8 ft. wherever practicable. For constant potential, direct-current circuits, not exceeding 750 volts, the minimum clearance above telegraph, telephone and similar wires may be 2 ft. with insulated wires and 4 ft. with bare wires.

11. The separation of conductors carrying alternating current, supported by pin insulators, for spans not exceeding 150 ft., shall be not less than:

Line Voltage.	Separation.
Not exceeding 6,600 volts	14½ in.
Exceeding 6,600, but not exceeding 14,000	24 in.
Exceeding 14,000, but not exceeding 27,000	30 in.
Exceeding 27,000, but not exceeding 35,000	36 in.
Exceeding 35,000, but not exceeding 47,000	45 in.
Exceeding 47,000, but not exceeding 70,000	60 in.

*For amendments, see index.

For spans exceeding 150 ft. the pin spacing should be increased, depending upon the length of the span and the sag of the conductors.

NOTE.—This requirement does not apply to wires of the same phase or polarity between which there is no difference of potential.

With constant potential, direct-current circuits not exceeding 750 volts, the minimum spacing shall be 10 in.

12. When supported by insulators of the disc or suspension type, the crossing span and the next adjoining spans shall be dead-ended at the poles, or towers, supporting the crossing span, so that at these poles, or towers, the insulators shall be used as strain insulators.

13. The clearance in any direction between the conductors nearest the pole, or tower, and the pole or tower shall be not less than:

Line Voltage.	Clearance.
Not exceeding 10,000 volts	9 in.
Exceeding 10,000, but not exceeding 14,000	12 in.
Exceeding 14,000, but not exceeding 27,000	15 in.
Exceeding 27,000, but not exceeding 35,000	18 in.
Exceeding 35,000, but not exceeding 47,000	21 in.
Exceeding 47,000, but not exceeding 70,000	24 in.

Conductors.

14. The normal mechanical tension in the conductors generally shall be the same in the crossing span and in the adjoining span on each side, and the difference in length of the crossing and adjoining spans generally shall be not more than 50 per cent. of the length of the crossing span.

15. The conductors shall not be spliced in the crossing span nor in the adjoining span on either side.

16. The method of supporting the conductors at the poles, or towers, shall be such as to hold the wires, under maximum loading, to the supporting structures, in case of shattered insulators, or wires broken or burned at an insulator, without allowing an amount of slip which would materially reduce the clearance specified in paragraphs No. 9 and No. 10.

Guys.

17. Wooden poles supporting the crossing span shall be side-guyed in both directions if practicable, and be head-guyed away from the crossing span. The next adjoining poles shall be head-guyed in both directions. Braces may be used instead of guys.

18. Strain insulators shall be used in guys from wooden poles carrying any power wire of less than 6,600 volts, provided the guys are not through grounded to permanently damp earth. Strain insulators shall not be used in guying steel structures, nor required on wooden poles carrying wires, all of which are 6,600 volts or more, provided the guys are through grounded to permanently damp earth.

Clearing.

19. The space around the poles, or towers, shall be kept free from inflammable material, underbrush and grass.

Signs.

20. In the case of railroad crossings, if required by the railroad company, warning signs of an approved design shall be placed on all poles and towers located on the railroad company's right-of-way.

Grounding.

21. For voltages over 5,000 volts, wooden crossarms, if used, shall be provided with a grounded metallic plate on top of the arm, which shall be not less than ⅛-in. in thickness and which shall have a sectional area and conductivity not less than that of the line conductor. Metal pins shall be electrically connected to this ground. Metal poles and metal arms on wooden poles shall be grounded.

22. The electrical conductivity of the ground conductor shall be adjusted to the short-circuit current capacity of the system and shall be not less than that of a No. 4 B. & S. gage copper wire.

Temperature.

23. In the computation of stresses and clearances, and in erection, provision shall be made for a variation in temperature from —20 degrees Fahrenheit to + 120 degrees Fahrenheit. A suitable modification in the temperature requirements shall be made for regions in which the above limits would not fairly represent the extreme range of temperature.

Inspection.

24. If required by contract, all material and workmanship shall be subject to the inspection of the company crossed; provided, that reasonable notice of the intention to make shop inspection shall be given by such company; if such notification is not given, the company crossed shall be furnished with certified reports of shop inspection of material and workmanship made by a properly qualified inspector. Defective material shall be rejected, and shall be removed and replaced with suitable material.

25. On the completion of the work, all false work, plant and rubbish, incident to the construction, shall be removed promptly and the site left unobstructed and clean.

Drawings.

26. If required, by contract, ... ( ) complete sets of general and detail drawings shall be furnished for approval, before any construction is commenced.

LOADS.

27. The conductors shall be considered as uniformly loaded throughout their length, with a load equal to the resultant of the dead load plus the weight of a layer of ice ½-in. in thickness, and a wind pressure of 8 lbs. per sq. ft. on the ice-covered diameter, at a temperature of 0 degrees Fahrenheit.

28. The weight of ice shall be assumed as 57 lbs. per cu. ft. (0.033 lbs. per cu. in.).

29. Insulators, pins and conductor attachments shall be designed to withstand, with the designated factor of safety, the tension in the con-

ductors under the maximum loading, assuming the conductor to be broken on one side of the structure.

30. The pole, or towers, shall be designed to withstand, with the designated factor of safety, the combined stresses from their own weight, the wind pressure on the pole, or tower, and the above wire loading on the crossing span and the next adjoining span on each side. The wind pressure on the poles, or towers, shall be assumed at 13 lbs. per sq. ft. on the projected area of solid or closed structures, and on 1½ times the projected area of latticed structures.

31. The poles, or towers, shall also be designed to withstand the most unfavorable condition of the loads specified in paragraph 30, combined with the unbalanced tension of

Two broken wires for poles, or towers, carrying 5 wires or less.

Three broken wires for poles, or towers, carrying 6 to 10 wires.

Four broken wires for poles, or towers, carrying 11 or more wires.

32. Crossarms shall be designed to withstand the loading specified in paragraph 30, combined with the unbalanced tension of the wire, which, when broken, produces the highest fiber stress in the arm.

33. The poles, or towers, may be permitted a reasonable deflection under the specified loading, provided that such deflection does not reduce the clearances specified in paragraph No. 10 more than 25 per cent. or produce stresses in excess of those specified in paragraphs Nos. 65 to 69.

FACTORS OF SAFETY.

34. The ultimate unit stress divided by the allowable stress shall be not less than the following:

Wires and cables	2
Pins	2
Insulators, conductor attachments, guys	3
Wooden poles and crossarms	6
Structural steel	3
Reinforced concrete poles and crossarms	4
Foundations	2

NOTE.—The treating of wooden poles and crossarms is recommended. The treatment of wooden poles and crossarms should be by thorough impregnation with preservative by either closed or open-tank process. For poles, except in the case of yellow pine, the treatment need not extend higher than a point 2 ft. above the ground line.

Insulators.

35. Insulators for line voltages of less than 9,000 shall not flash over at four times the normal working voltage, under a precipitation of water of 1/5 of an in. per minute, at an inclination of 45 degrees to the axis of the insulator.

36. Each separate part of a built-up insulator, for line voltages over 9,000, shall be subjected to the dry flash-over test of that part for five consecutive minutes.

37. Each assembled and cemented insulator shall be subjected to its dry flash-over test for five consecutive minutes.

The dry flash-over test shall be not less than:

Line Voltage.	Test Voltage.
Exceeding 9,000, but not exceeding 14,000....	65,000
Exceeding 14,000, but not exceeding 27,000....	100,000
Exceeding 27,000, but not exceeding 35,000....	125,000
Exceeding 35,000, but not exceeding 47,000....	150,000
Exceeding 47,000, but not exceeding 60,000....	180,000
Exceeding 60,000	3 times line voltage

Each insulator shall further be so designed that, with excessive potential, failure will first occur by flash-over and not by puncture.

38. Each assembled insulator shall be subjected to a wet flash-over test, under a precipitation of water of 1-5 in. per minute, at an inclination of 45 degrees to the axis of the insulator.

The wet flash-over test shall be not less than:

Line Voltage.	Test Voltage.
Exceeding 9,000, but not exceeding 14,000...	40,000
Exceeding 14,000, but not exceeding 27,000...	60,000
Exceeding 27,000, but not exceeding 35,000...	80,000
Exceeding 35,000, but not exceeding 47,000...	100,000
Exceeding 47,000, but not exceeding 60,000...	120,000
Exceeding 60,000	twice the line voltage.

39. Test voltages above 35,000 volts shall be determined by the A. I. E. E. Standard Spark-Gap Method.

40. Test voltages below 35,000 volts shall be determined by transformer ratio.

MATERIAL.

Conductors.

41. The conductors shall be of copper, aluminum, or other noncorrodible material, except that in exceptionally long spans, where the required mechanical strength cannot be obtained with the above materials, galvanized or copper-covered steel strand may be used.

42. For voltages not exceeding 750 volts, solid or stranded conductors may be used up to and including 4/0 in size; above 4/0 in size, stranded conductors shall be used. For voltages exceeding 750 volts, and not exceeding 5,000 volts, solid or stranded conductors may be used up to and including 2/0 in size; above 2/0 in size, conductors shall be stranded. For voltages exceeding 5,000 volts, all conductors shall be stranded. Aluminum conductors for all voltages and sizes shall be stranded.

The minimum size of conductors shall be as follows:

No. 6 B. & S. gage copper for voltages not exceeding 5,000 volts.

No. 4 B. & S. gage copper for voltages exceeding 5,000 volts.

No. 1 B. & S. gage aluminum for all voltages.

Insulators.

43. Insulators shall be of porcelain for voltages exceeding 5,000 volts.

44. Strain insulators for guys shall have an ultimate strength of not less than twice that of the guy in which placed. Strain insulators shall be so constructed that the guy wires holding the insulator in position will interlock in case of the failure of the insulator.

Strain insulators for guys shall not flash over at four times the maximum line voltage, under a precipitation of water of 1/5 in. per minute, at an inclination of 45 degrees to the axis of the insulator.

Pins.

45. For voltages of 5,000 and over, insulator pins shall be steel, wrought iron, malleable iron, or other approved metal or alloy, and shall be galvanized, or otherwise protected from corrosion. Pins shall be locked with cotter, nut, or other device, to prevent raising out of the socket or hole in the crossarm.

Guys.

46. Guys shall be galvanized or copper-covered stranded steel cable not less than 5/16-in. in diameter, or galvanized rolled rods of equivalent tensile strength.

47. Guys to the ground shall connect to a galvanized anchor rod, extending at least one foot above the ground level.

48. The detail of the anchorage shall be definitely shown upon the plans.

Wooden Poles.

49. Wooden poles shall be of selected timber of approved species, peeled, free from defects which would decrease their strength or durability, not less than 7 in. minimum diameter at the top, and meeting the requirments as specified in paragraphs 17, 30, 31 and 34.

Concrete.

50. All concrete and concrete material shall be in accordance with the requirements of the Report of the Joint Committee on Concrete and Reinforced Concrete.

STRUCTURAL STEEL.

51. Structural steel shall be open-hearth, in accordance with the Manufacturers' Standard Specifications.

52. The design and workmanship shall be strictly in accordance with first-class practice.

53. The form of the frame shall be such that the stresses may be computed with reasonable accuracy, or the strength shall be determined by actual test.

54. The sections used shall permit inspection, cleaning and painting, and shall be free from pockets in which water or dirt can collect.

55. The length of a main compression member shall not exceed 150 times its least radius of gyration. The length of a secondary compression member shall not exceed 180 times its least radius of gyration.

56. The minimum thickness of metal in galvanized structures shall

be ¼-in. for main members, and ⅛-in. for secondary members. The minimum thickness of painted material shall be ¼-in.

PROTECTIVE COATINGS.

57. All structural steel shall be thoroughly cleaned at the shop and be galvanized, or given one coat of approved paint.

Painted Material.

58. All contact surfaces shall be given one coat of paint before assembling.

All painted structural steel shall be given two field coats of an approved paint.

The surface of the metal shall be thoroughly cleaned of all dirt, grease, scale, etc., before painting, and no painting shall be done in freezing or rainy weather.

Galvanized Material.

59. Galvanized material shall be in accordance with the Specifications for Galvanizing Iron and Steel (Appendix).

Bolt holes in galvanized material shall be made before galvanizing.

FOUNDATIONS.

60. The foundations for steel poles and towers shall be designed to prevent overturning.

The weight of concrete shall be assumed as 140 lbs. per cu. ft. In good ground, the weight of "earth" shall be assumed at 100 lbs. per cu. ft. In swampy ground, special measures shall be taken to prevent uplift or depression.

61. The top of the concrete foundation, or casing, shall be not less than 12 in. above the surface of the ground or extreme high water.

62. When located in swampy ground, wooden crossing and next adjoining poles shall be set in barrels of broken stone or gravel, or in broken stone or timber footings.

63. When located in the sides of banks, or when subject to washouts, foundations shall be given additional depth, or be protected by cribbing or riprap.

64. All foundations and pole settings shall be tamped in 6-in. layers, while back filling.

WORKING UNIT STRESSES.

Obtained by dividing the ultimate breaking strength by the factors of safety given in paragraph 34.

Structural Steel.

	Lbs. per sq. in.
65. Tension (net section)	18,000
Shear	14,000
Compression	$18{,}000 - 60\frac{l}{r}$

Rivets, Pins.

66. Shear 10,000
Bearing 20,000
Bending 20,000

Bolts.

67. Shear 8,500
Bearing 17,000
Bending 17,000

Wires and Cables.

	Lbs. per sq. in.
68. Copper, hard-drawn, solid, B. & S. gage, 4/0, 3/0, 2/0	25,000
Copper, hard-drawn, solid, B. & S. gage, 1/0	27,500
Copper, hard-drawn, solid, B. & S. gage, No. 1	28,500
Copper, hard-drawn, solid, B. & S. gage, No. 2, 4, 6	30,000
Copper, soft-drawn, solid, B. & S.	17,000
Copper, hard-drawn, stranded, B. & S.	30,000
Copper, soft-drawn, stranded, B. & S.	17,000
Aluminum, hard-dr'n, stranded, B. & S. gage under 4/0	12,000
Aluminum, hard-dr'n, stranded, B. & S. gage 4/0 and over	11,500

Untreated Timber.

	Bending.	Compression.
69. Eastern white cedar	600 lbs. per sq. in.	$600\left(1-\frac{L}{60\,D}\right)$
Chestnut	850 lbs. per sq. in.	850 "
Washington cedar	850 lbs. per sq. in.	850 "
Idaho cedar	850 lbs. per sq. in.	850 "
Port Orford cedar	1150 lbs. per sq. in.	1150 "
Long-leaf yellow pine	1100 lbs. per sq. in.	1100 "
Short-leaf yellow pine	950 lbs. per sq. in.	950 "
Douglas fir	1000 lbs. per sq. in.	1000 "
White oak	950 lbs. per sq. in.	950 "
Red cedar	700 lbs. per sq. in.	700 "
Bald cypress (heartw'd)	800 lbs. per sq. in.	800 "
Redwood	850 lbs. per sq. in.	850 "
Catalpa	500 lbs. per sq. in.	500 "
Juniper	550 lbs. per sq. in.	550 "

L = Length in inches.
D = Least side, or diameter, in inches.

SPECIFICATION FOR GALVANIZING FOR IRON OR STEEL.

These specifications give in detail the test to be applied to galvanized material. All specimens shall be capable of withstanding these tests.

Coating.

(A) The galvanizing shall consist of a continuous coating of pure zinc of uniform thickness, and so applied that it adheres firmly to the surface of the iron or steel. The finished product shall be smooth.

Cleaning.

(B) The samples shall be cleaned before testing, first with carbona, benzine or turpentine and cotton waste (not with a brush), and then thoroughly rinsed in clean water and wiped dry with clean cotton waste.

The sample shall be clean and dry before each immersion in the solution.

Solution.

(C) The standard solution of copper sulphate shall consist of commercial copper sulphate crystals dissolved in cold water, about in the proportion of 36 parts, by weight, of crystals to 100 parts, by weight, of water. The solution shall be neutralized by the addition of an excess of chemically pure cupric oxide (Cu O). The presence of an excess of cupric oxide will be shown by the sediment of this reagent at the bottom of the containing vessel.

The neutralized solution shall be filtered before using by passing through filter paper. The filtered solution shall have a specific gravity of 1.186 at 65 degrees Fahrenheit (reading the scale at the level of the solution) at the beginning of each test. In case the filtered solution is high in specific gravity, clean water shall be added to reduce the specific gravity at 1.186 at 65 degrees Fahrenheit. In case the filtered solution is low in specific gravity, filtered solution of a higher specific gravity shall be added to make the specific gravity 1.186 at 65 degrees Fahrenheit.

As soon as the stronger solution is taken from the vessel containing the unfiltered neutralized stock solution, additional crystals and water must be added to the stock solution. An excess of cupric oxide shall always be kept in the unfiltered stock solution.

Quantity of Solution.

(D) Wire samples shall be tested in a glass jar of at least 2 in. inside diameter. The jar without the wire samples shall be filled with standard solution to a depth of at least 4 in. Hardware samples shall be tested in a glass or earthenware jar containing at least ½ pint of standard solution for each hardware sample.

Solution shall not be used for more than one series of four immersions.

Samples.

(E) Not more than seven wires shall be simultaneously immersed, and not more than one sample of galvanized material other than wire shall be immersed in the specified quantity of solution.

The samples shall not be grouped or twisted together, but shall be

well separated so as to permit the action of the solution to be uniform upon all immersed portions of the samples.

Test.

(F) Clean and dry samples shall be immersed in the required quantity of standard solution in accordance with the following cycle of immersions.

The temperature of the solution shall be maintained between 62 degrees and 68 degrees Fahrenheit at all times during the following test.

(1) Immerse for one minute, wash and wipe dry.
(2) Immerse for one minute, wash and wipe dry.
(3) Immerse for one minute, wash and wipe dry.
(4) Immerse for one minute, wash and wipe dry.

After each immersion the samples shall be immediately washed in clean water having a temperature between 62 degrees and 68 degrees Fahrenheit, and wiped dry with cotton waste.

In the case of No. 14 galvanized iron or steel wire, the time of the fourth immersion shall be reduced to ½ minute.

Rejection.

(G) If after the test described in section (F) there should be a bright metallic copper deposit upon the samples, the lot represented by the sample shall be rejected.

Copper deposits on zinc or within 1 in. of the cut end shall not be considered causes for rejection.

In the case of a failure of only one wire in a group of seven wires immersed together, or if there is a reasonable doubt as to the copper deposit, two check tests shall be made on these seven wires and the lot reported in accordance with the majority of the sets of tests.

NOTE.—The equipment necessary for the tests herein outlined is as follows:

Filter paper.
Commercial copper sulphate crystals.
Chemically pure cupric oxide (Cu O).
Running water.
Warm water or ice, as per needs.
Carbona, benzine or turpentine
Glass jars at least 2 in. inside diameter by at least 4½ in. high.
Glass or earthenware jars for hardware samples.
Vessel for washing samples.
Tray for holding jars of stock solution.
Jars, bottles and porcelain basket for stock solution
Cotton waste.
Hydrometer cylinder 3 in. diameter by 15 in. high
Thermometer with large Fahrenheit scale correct at 62 and 68 degrees
Hydrometer correct at 1.180 at 65 degrees Fahrenheit

Appendix B.

PARAGRAPHS IN SPECIFICATIONS FOR OVERHEAD CROSSING OF ELECTRIC LIGHT AND POWER LINES AS ADOPTED BY OTHER ASSOCIATIONS REFERRED TO IN REPORT OF COMMITTEE ON ELECTRICITY.

10. The clearance of alternating-current circuits above any existing wires, under the most unfavorable condition of temperature and loading, shall be not less than 8 ft. wherever possible. For constant potential, direct-current circuits, not exceeding 750 volts, the minimum clearance above telegraph, telephone and similar wires may be 2 ft. with insulated wires and 4 ft. with bare wires.

13. The clearance in any direction between the conductors nearest the pole, or tower, and the pole, or tower, shall be not less than:

Line Voltage.	Clearances.
Not exceeding 14,000 volts	9 in.
Exceeding 14,000 but not exceeding 27,000	15 in.
Exceeding 27,000 but not exceeding 35,000	18 in.
Exceeding 35,000 but not exceeding 47,000	21 in.
Exceeding 47,000 but not exceeding 70,000	24 in.

18. Strain insulators shall be used in guys from wooden poles carrying any power wire of less than 6,600 volts. Strain insulators shall not be used in guying steel structures, nor required on wooden poles carrying wires all of which are 6,600 volts or more.

Inspection.

24. If required by contract, all material and workmanship shall be subject to the inspection of the company crossed; provided that reasonable notice of the intention to make shop inspection shall be given by such company. Defective material shall be rejected, and shall be removed and replaced with suitable material.

29. Insulators, pins and conductor attachments shall be designed to withstand, with the designated factor of safety, the tension in the conductors under the maximum loading.

31. The poles, or towers, shall also be designed to withstand the loads specified in paragraph No. 30, combined with the unbalanced tension of:

Two broken wires for poles, or towers, carrying 5 wires or less.

Three broken wires for poles, or towers, carrying 6 to 10 wires.

Four broken wires for poles, or towers, carrying 11 or more wires.

32. Crossarms shall be designed to withstand the loading specified in paragraph No. 30, combined with the unbalanced tension of one wire broken at the pin farthest from the pole.

34. The ultimate unit stress divided by the allowable unit stress shall be not less than the following:

Wires and cables.....2
Pins 2
Insulator, conductor attachments, guys.....3
Wooden poles and crossarms.....6
Structural steel 3
Reinforced concrete poles and crossarms.....4
Foundations 2

Note:—The use of treated wooden poles and crossarms is recommended. The treatment of wooden poles and crossarms should be by thorough impregnation with preservative by either closed or open-tank process. For poles, except in the case of yellow pine, the treatment need not extend higher than a point 2 ft. above the ground line.

Pins.

45. For voltages of 5,000 and over, insulator pins shall be of steel, wrought iron, malleable iron, or other approved metal or alloy, and shall be galvanized, or otherwise protected from corrosion.

Wooden Poles.

49. Wooden poles shall be of selected timber, peeled, free from defects which would decrease their strength or durability, not less than 7 in. minimum diameter at the top, and meeting the requirements as specified in paragraphs 17, 30, 31 and 34.

51. Structural steel shall be in accordance with the Manufacturers' Standard Specifications.

55. The length of a main compression member shall not exceed 180 times its least radius of gyration. The length of a secondary compression member shall not exceed 220 times its least radius of gyration.

60. The foundations for steel poles and towers shall be designed to prevent overturning.

The weight of concrete shall be assumed as 140 lbs. per cu. ft. In good ground, the weight of "earth" (calculated at 30 degrees from the vertical) shall be assumed as 100 lbs. per cu. ft. In swampy ground, special measures shall be taken to prevent uplift or depression.

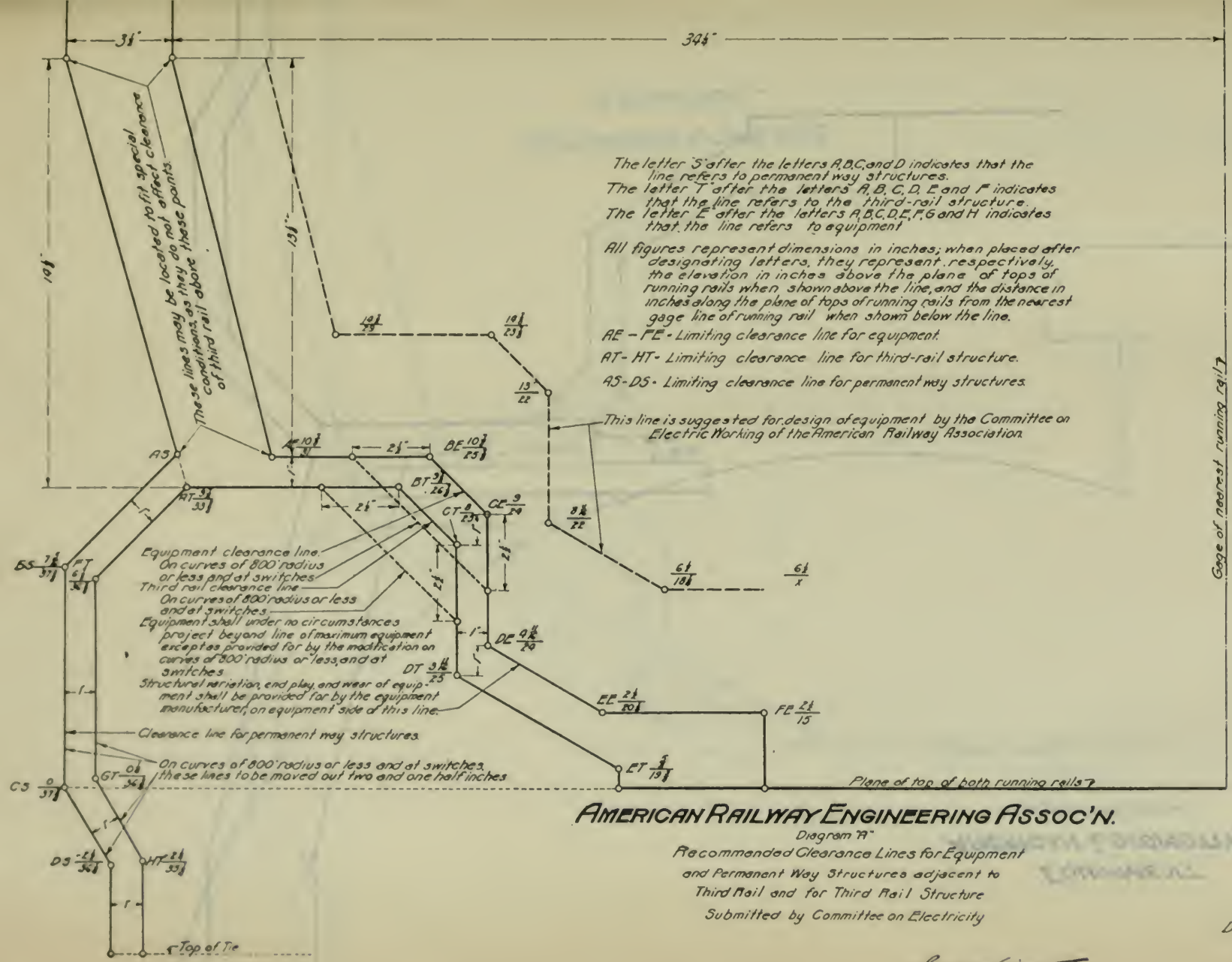
61. The top of the concrete foundation, or casing, shall be not less than 6 in. above the surface of the ground, nor less than 1 ft. above extreme high water.

DATA REGARDING THIRD RAIL CLEARANCES.

Revised February 1, 1912.

Name of Company	Plan No.	Top or Under Contact	Protected	Uses Steam Equipment	Structures Clear Prop. Lines	Mileage in Operation	Mileage Planned for Immed. Future	Mileage Using Steam Equipment	Mileage Clearing Proposed Lines
Albany Southern	1	Top	No	Yes	Yes	65.00	.....	65.00	65.00
Aurora, Elgin & Chicago	2	"	"	"	No	95.00	.....	95.90	.....
Baltimore & Ohio	3	"	Yes	"	Slight	8.70	.....	8.70	8.70
Boston Elevated Ry.	4	"	No	No	No	24.52	.....	.....	.....
Brooklyn Rapid Transit	5	"	"	"	"	87.99	.....	.....	.....
Northwestern Elevated, Chicago	6	"	"	"	"	60.00	.....	.....	.....
Central California Traction	7	Under	Yes	Yes	Yes	45.00	.....	45.00	45.00
Grand Rapids, Grand Haven & Muskegon	8	Top	No	No	No	41.26	.....	.....	.....
Hudson & Manhattan	9	"	Yes	"	"	17.50	2.35	.....	.....
Interborough Rapid Transit	10, 11, 12	"	Partly	"	"	203.31	.....	.....	.....
Lackawanna & Wyoming Valley	14	"	No	Yes	"	44.00	.....	44.00	.....
Long Island R. R.	13, 18	"	Yes	"	Yes	166.03	.....	166.03	166.03
Metropolitan West Side, Chicago	6	"	No	No	No	49.64	.....	.....	.....
Michigan United	16	"	"	Yes	"	107.00	.....	107.00	.....
Northern Electric Ry., Chico, Cal.	17	"	"	"	"	130.00	.....	130.00	.....
Penna. Tunnel & Terminal Co.	18	"	Yes	"	Yes	94.52	.....	94.52	94.52
Puget Sound Electric Ry.	19	"	No	"	No	37.50	.....	37.50	.....
Philadelphia & Western	20	Under	Yes	"	"	22.00	12.00	34.00	.....
Scioto Valley Traction Co.	21	Top	No	"	Yes	65.82	.....	65.82	65.82
*Southern Pacific R. R.	.....	.....	.....	....	....	.....	.....	.....	.....
South Side Elevated, Chicago.	6	"	"	No	No	46.41	.....	.....	.....
West Jersey & Sea Shore	23	"	Yes	Yes	Yes	143.00	.....	143.00	143.00
Wilkesbarre & Hazelton	24	"	"	"	Slight	29.50	.....	29.50	.....
N. Y. C. & H. R. R. R.	26	Under	"	"	Yes	154.94	90.66	245.60	154.94
N. Y. C. & H. R. R. R., Utica to Syracuse	25	"	"	"	"	105.76	.....	105.76	105.76
Detroit River Tunnel Co.	26	"	"	"	"	19.27	.....	19.27	19.27
Phila. Rapid Transit Co.	.....	"	"	No	No	18.61	.....	.....	.....
Oneida Railway Co.	25	"	"	Yes	Yes	105.76	.....	96.23	105.76
Totals						1,988.04	105.01	1,531.93	973.80

*Single Catenary construction.


34½"
3½"
101"
13½"
These lines may be located to fit special conditions as they do not affect clearance of third rail above these points.
Gage of nearest running rail
Plane of top of both running rails
The letter 'S' after the letters A, B, C and D indicates that the line refers to permanent way structures.
The letter 'T' after the letters A, B, C, D, E and F indicates that the line refers to the third-rail structure.
The letter 'E' after the letters A, B, C, D, E, F, G and H indicates that the line refers to equipment
All figures represent dimensions in inches; when placed after designating letters, they represent, respectively, the elevation in inches above the plane of tops of running rails when shown above the line, and the distance in inches along the plane of tops of running rails from the nearest gage line of running rail when shown below the line.
AE – FE - Limiting clearance line for equipment.
AT - HT - Limiting clearance line for third-rail structure.
AS - DS - Limiting clearance line for permanent way structures.
This line is suggested for design of equipment by the Committee on Electric Working of the American Railway Association.
AS
AT 3/33
BT 3/26
CT 0/23½
DT 3½/25
ES 7½/37½
FT 6/36
GT 0/36½
CS 0/37½
DS -2½/36½
HT 2½/33½
AE 10½/29
BE 10½/23½
CE 9/19
DE 9½/20
EE 2½/20½
FE 2½/15
GE 8½/22
HE 13/22
IE 19½/23½
JE 19½/29
KE 10½/31
LE 6½/18½
ME 6½/x
2½"
1"
Equipment clearance line. On curves of 800' radius or less and at switches.
Third rail clearance line. On curves of 800' radius or less and at switches.
Equipment shall under no circumstances project beyond line of maximum equipment except as provided for by the modification on curves of 800' radius or less, and at switches.
Structural variation, end play, and wear of equipment shall be provided for by the equipment manufacturer, on equipment side of this line.
Clearance line for permanent way structures.
On curves of 800' radius or less and at switches these lines to be moved out two and one half inches
℄ Top of Tie

AMERICAN RAILWAY ENGINEERING ASSOC'N.

Diagram "A"

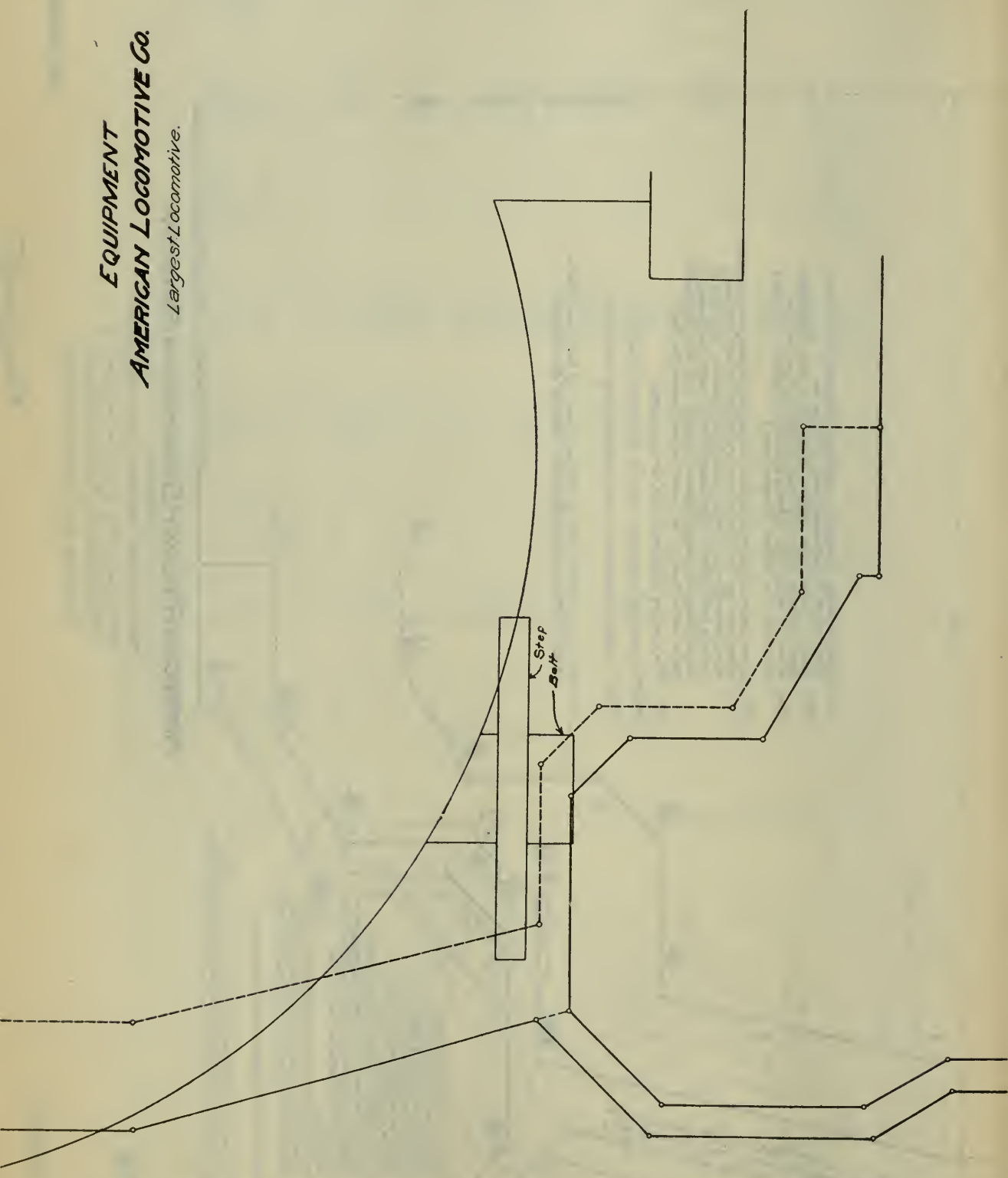
Recommended Clearance Lines for Equipment and Permanent Way Structures adjacent to Third Rail and for Third Rail Structure

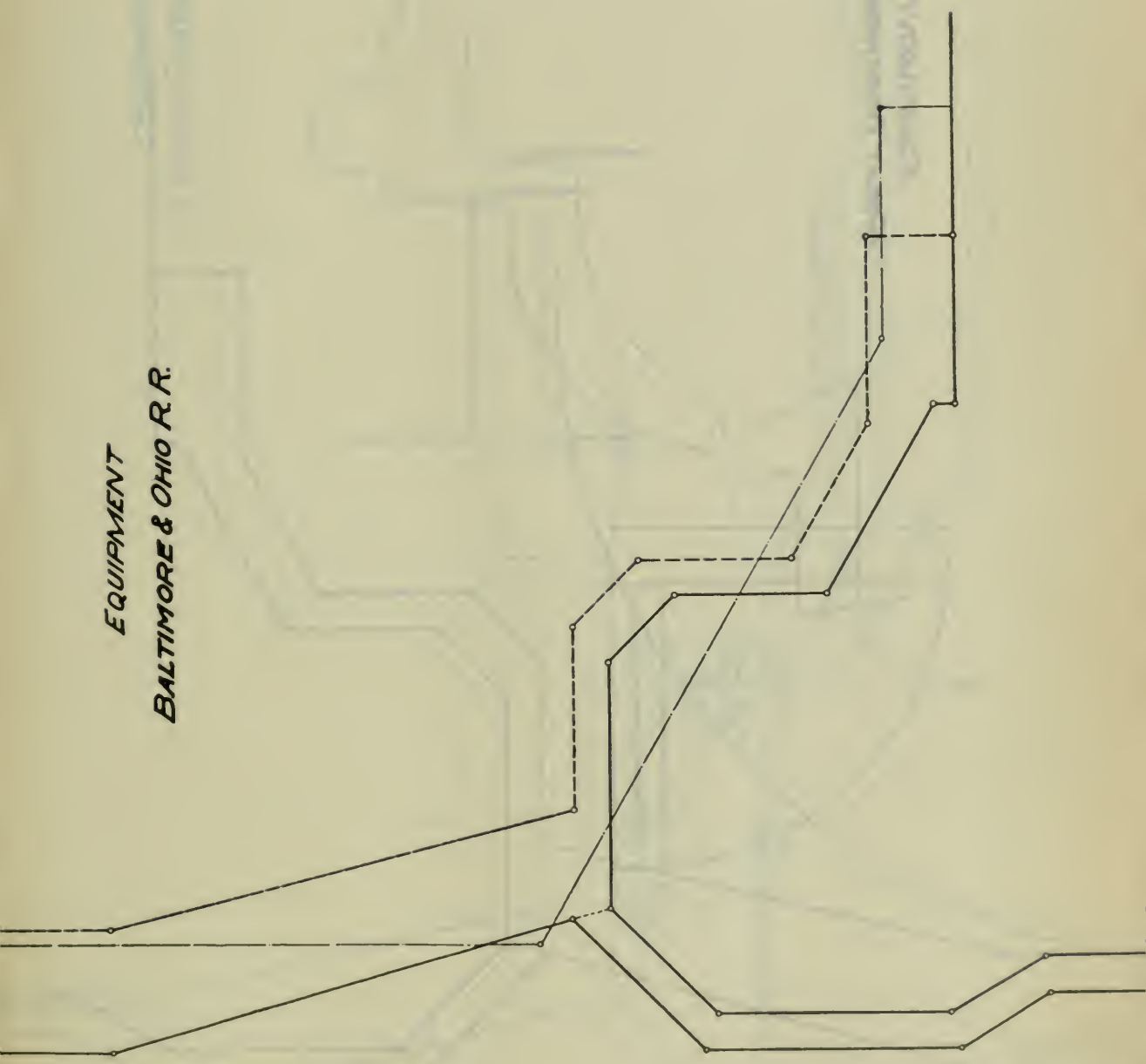
Submitted by Committee on Electricity

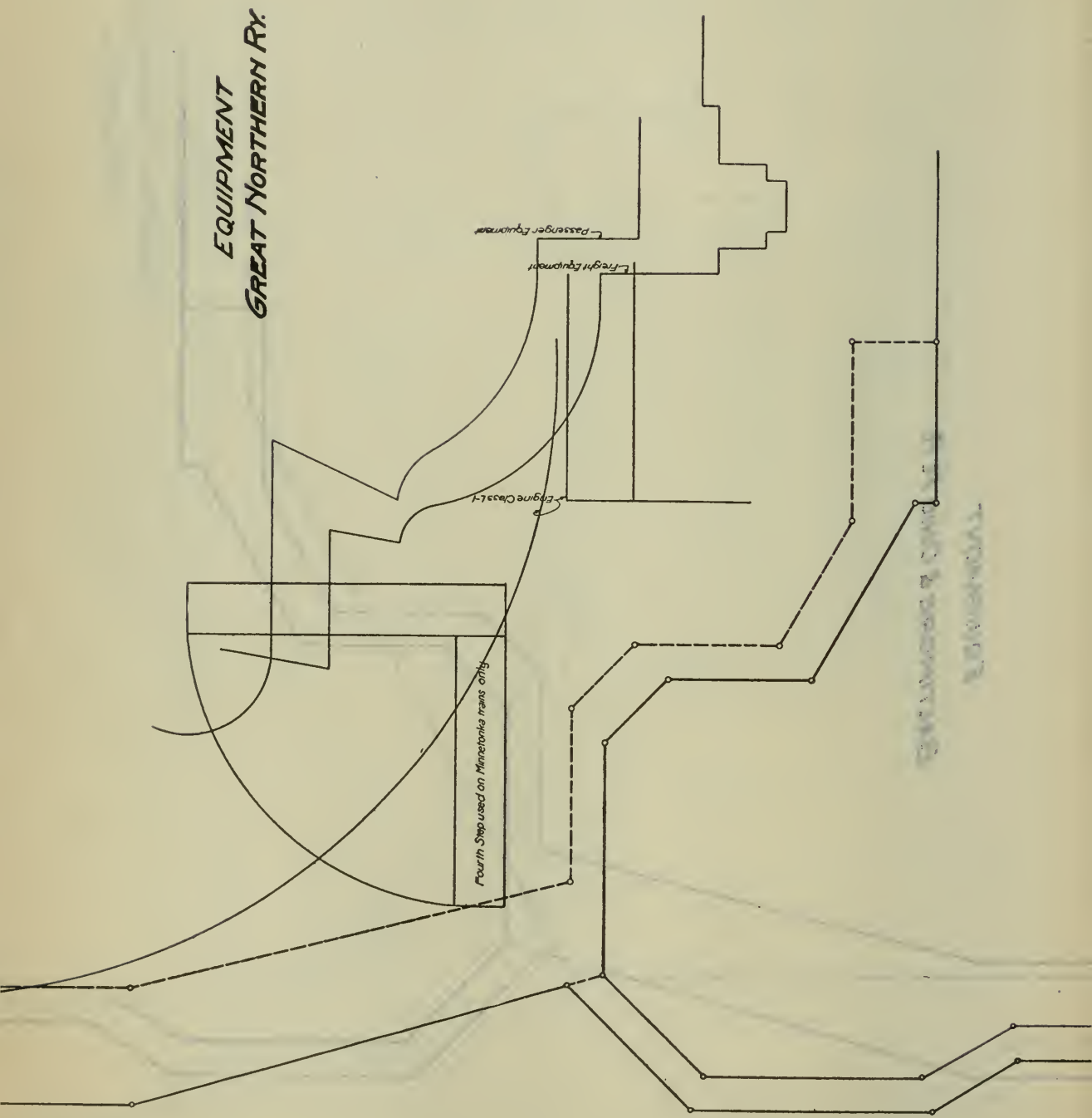
Date: January, 1912

George Hastings
Chairman

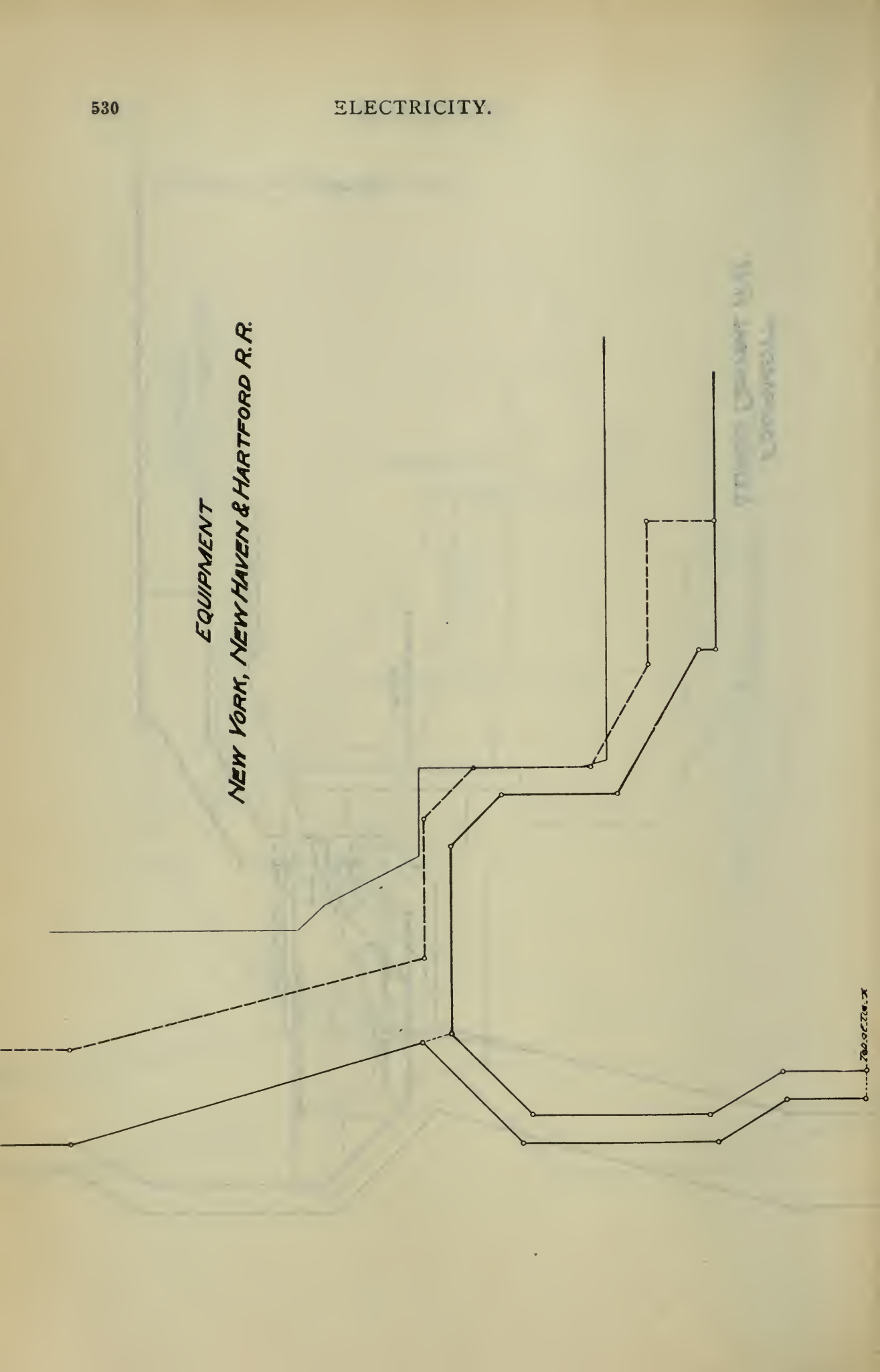
EQUIPMENT
AMERICAN LOCOMOTIVE CO.
Largest Locomotive.

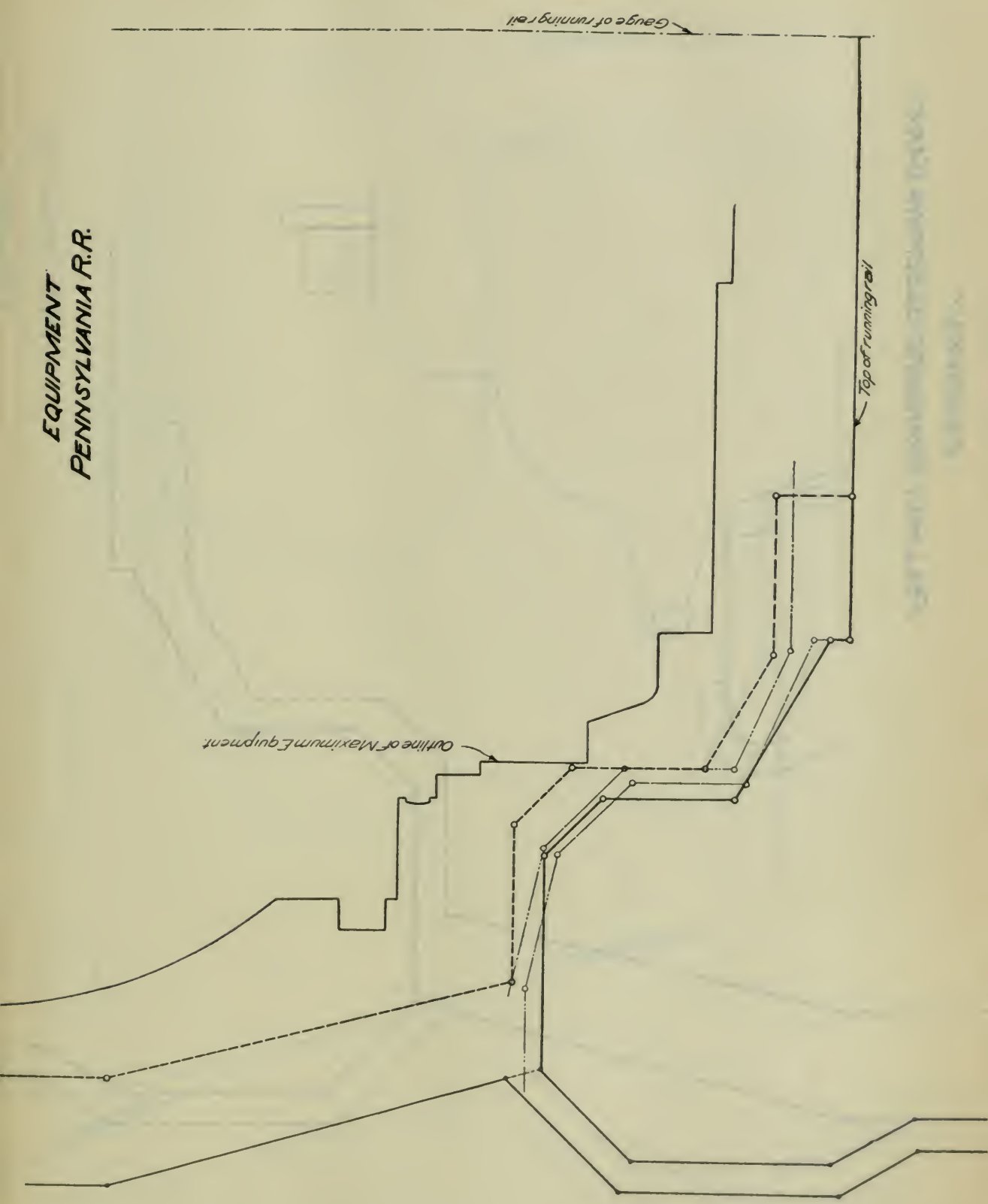


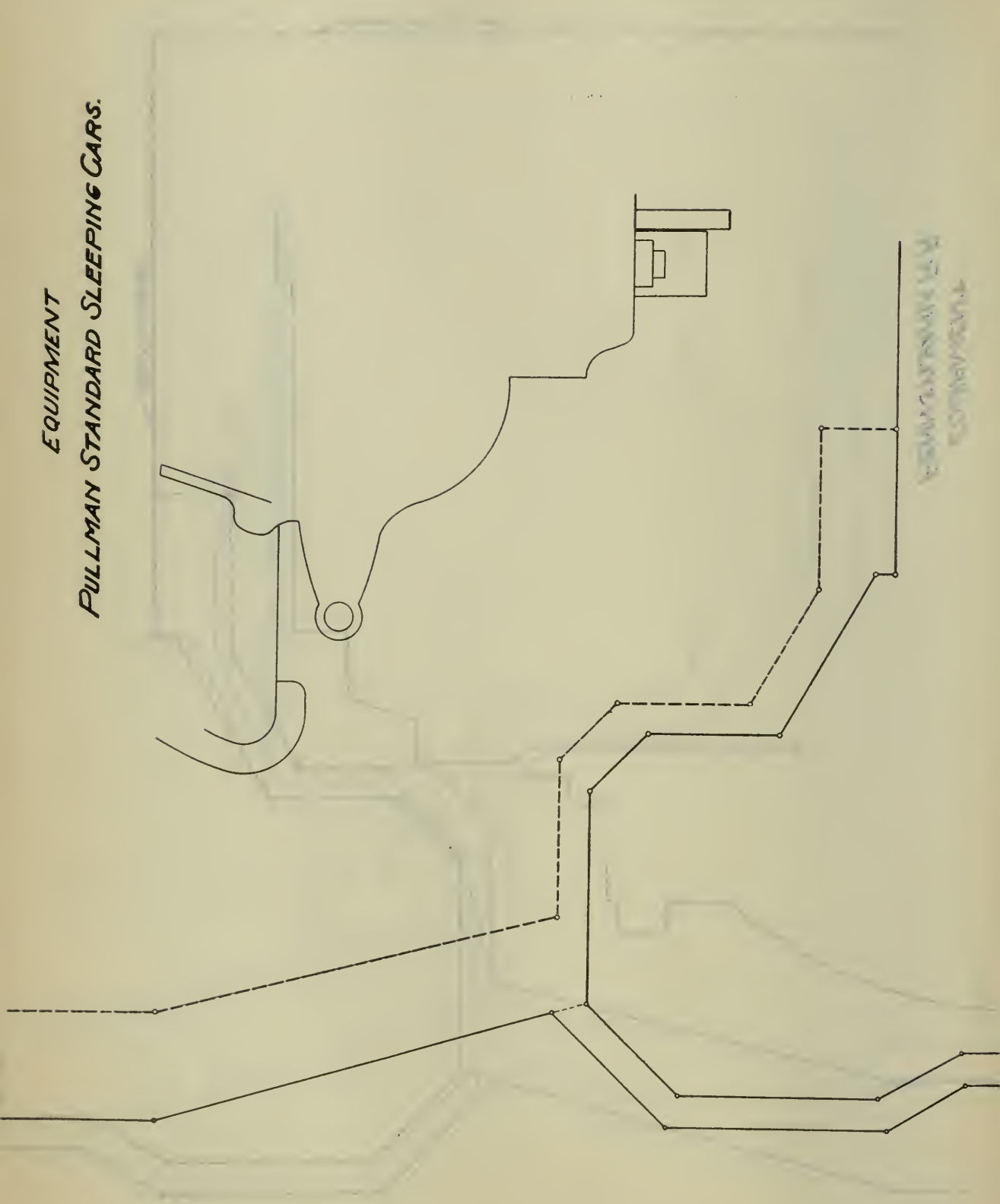

EQUIPMENT
BALTIMORE & OHIO R.R.


EQUIPMENT
GREAT NORTHERN RY.
Passenger Equipment
Freight Equipment
Engine Class L-1
Fourth Step used on Minnetonka trains only

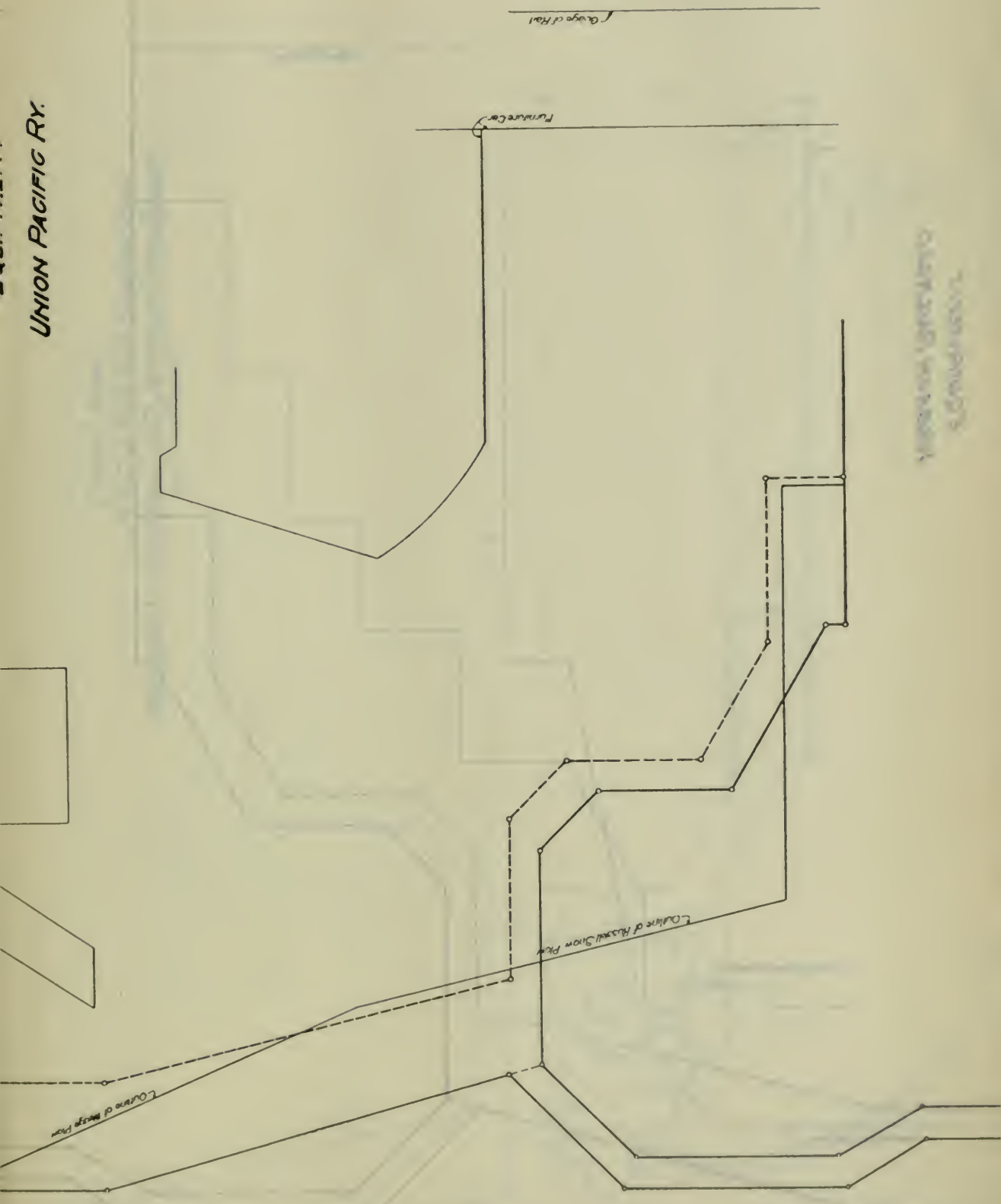
EQUIPMENT
ILLINOIS CENTRAL R.R.
Crank pin on engines 641-644
20° Curve
75 Ton Wrecker on 20° Curve
100 ton Shear Crane on 20° Curve
Shop on 30 ton flat car 20° Curve

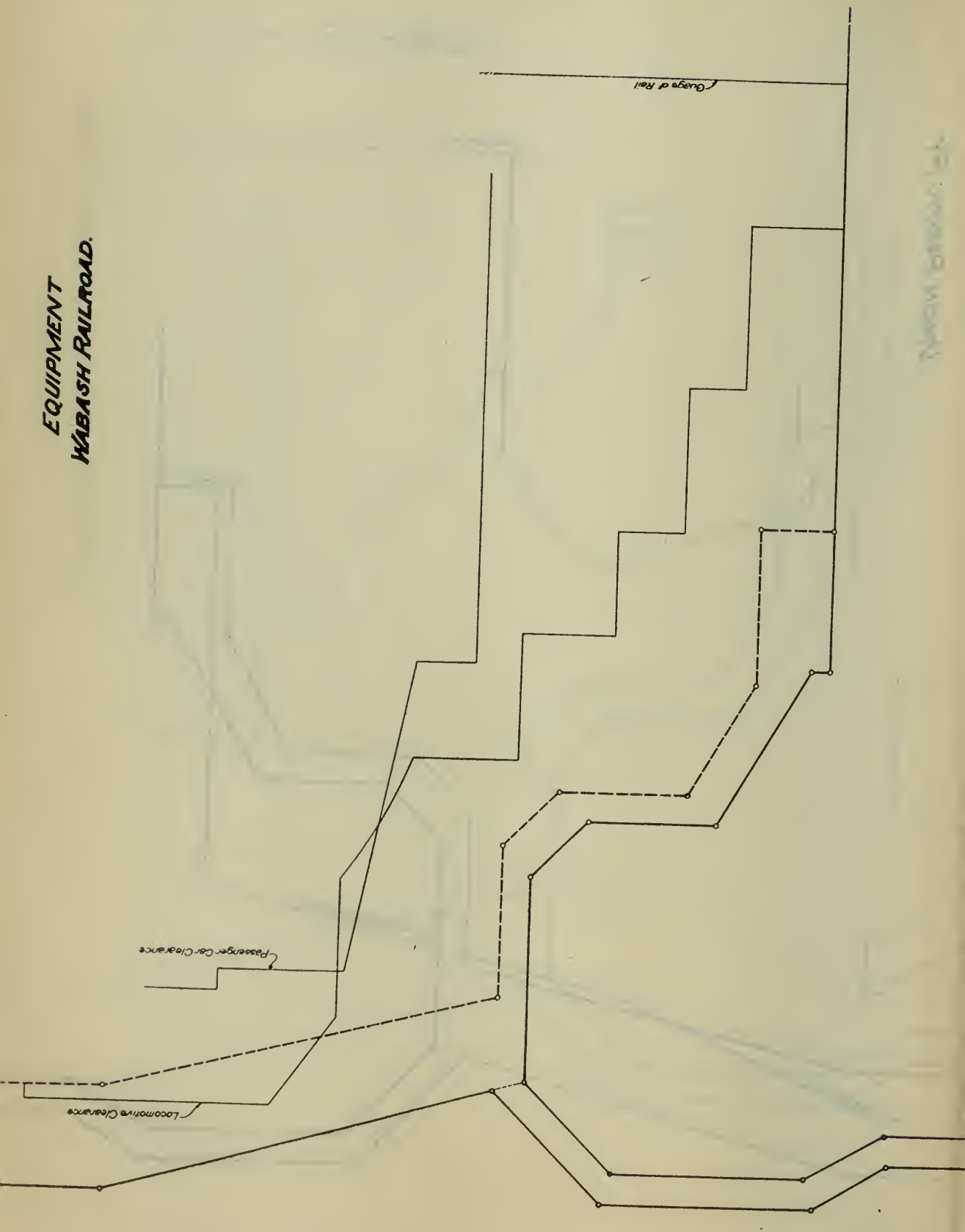

EQUIPMENT
NEW YORK, NEW HAVEN & HARTFORD R.R.


Gauge of running rail
Top of running rail
Outline of Maximum Equipment
EQUIPMENT
PENNSYLVANIA R.R.

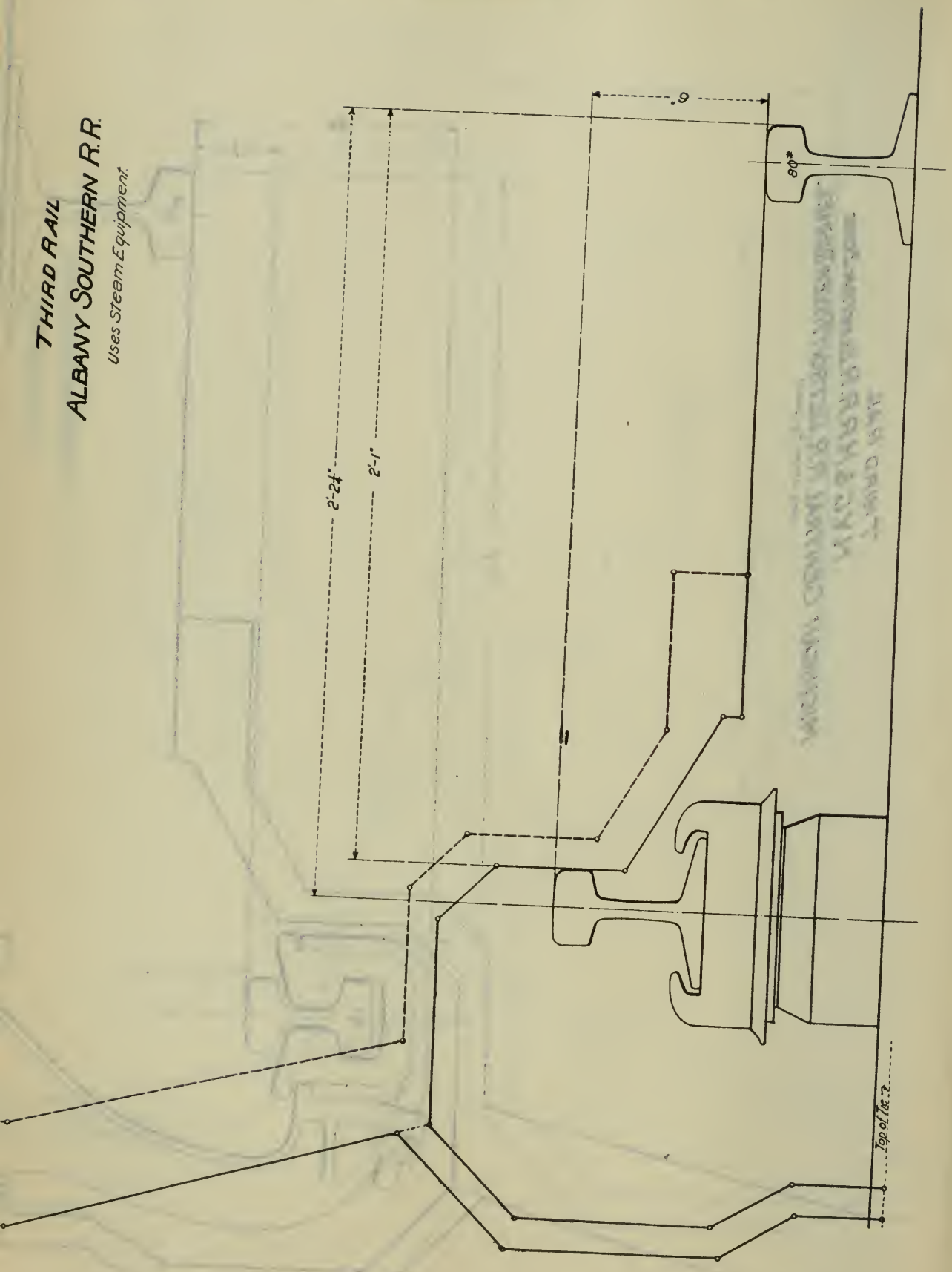


EQUIPMENT
PULLMAN STANDARD SLEEPING CARS.


Union Pacific Ry.


EQUIPMENT
WABASH RAILROAD.
Gauge of Rail
Passenger Car Clearance
Locomotive Clearance

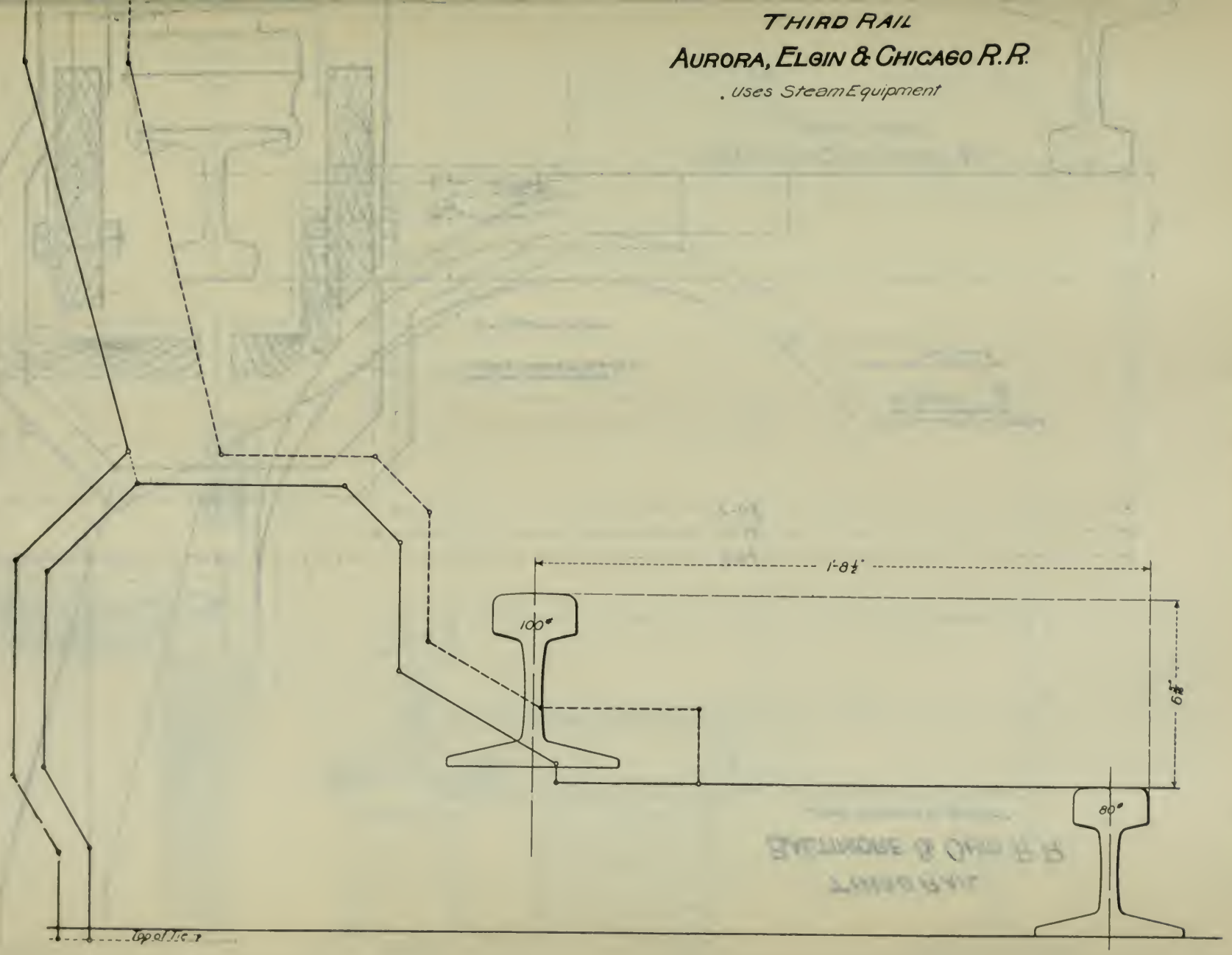
THIRD RAIL
N.Y.C. & H.R.R.R. ELECTRIC ZONE
MICHIGAN CENTRAL R.R. DETROIT RIVER TUNNEL.
Uses Steam Equipment
10"
2 1/2"
40°
2'-11"
70°
2 1/2"

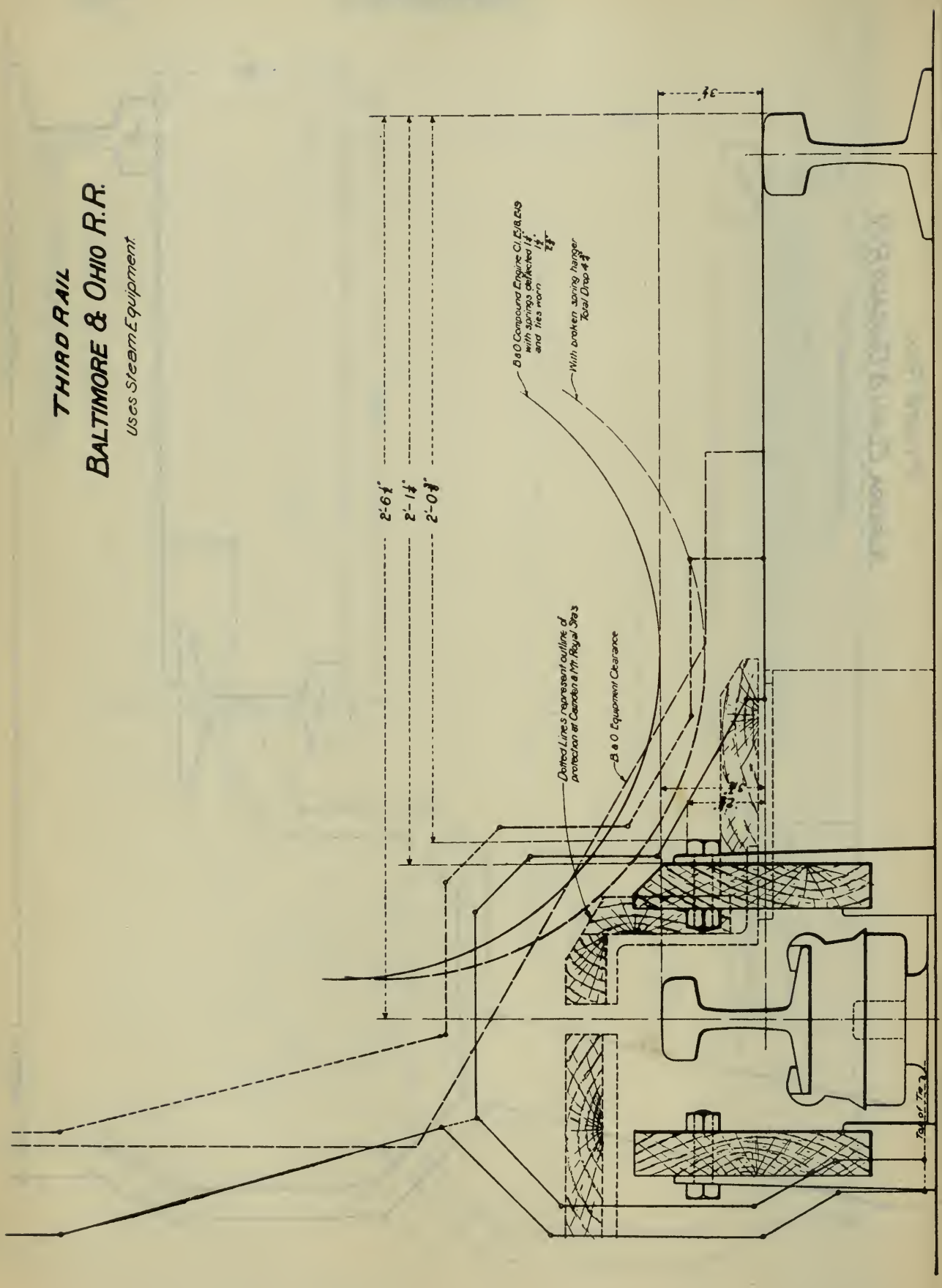

THIRD RAIL
ALBANY SOUTHERN R.R.
Uses Steam Equipment
.9
80*
2'-2"
2'-1"
Top of Tie

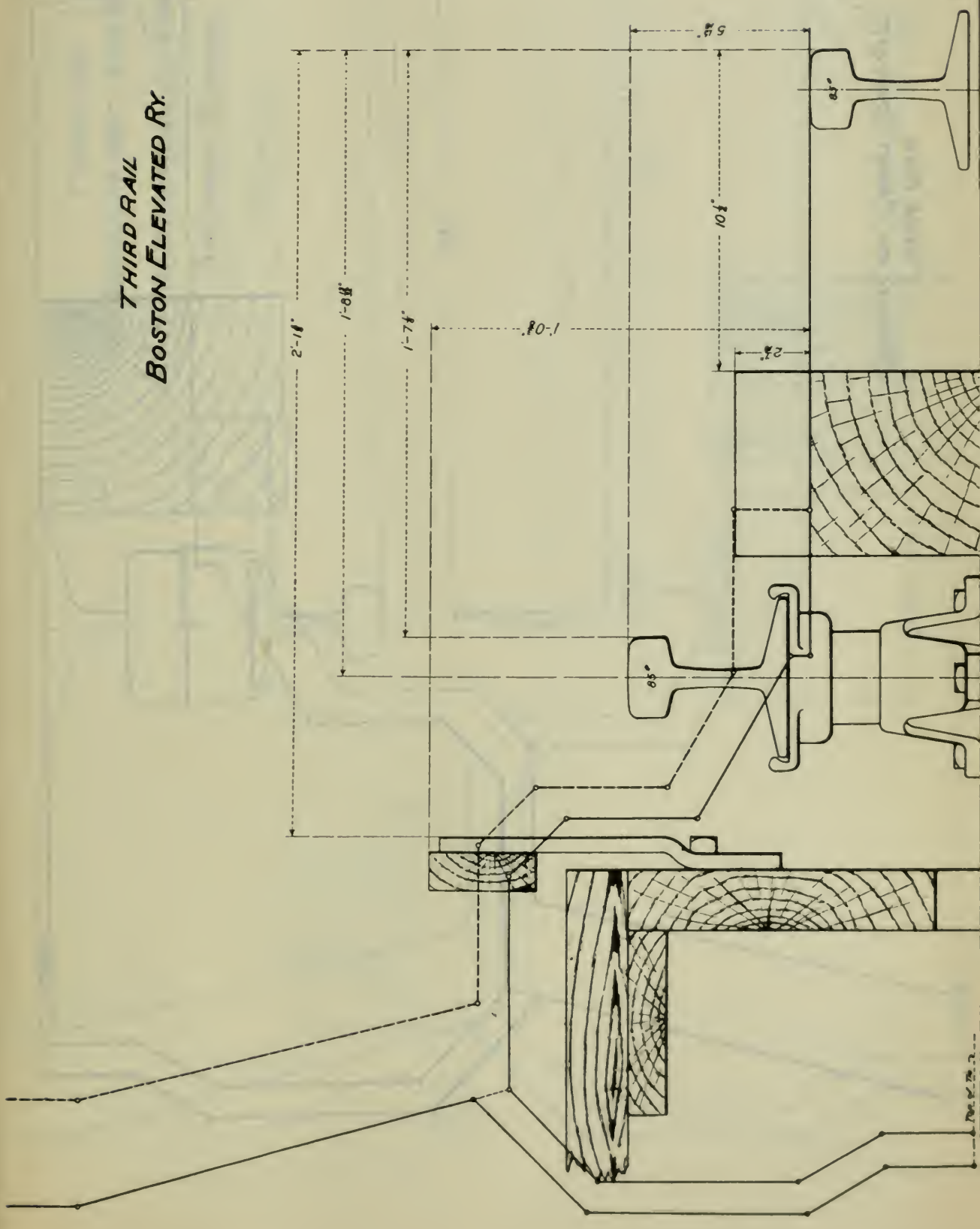
THIRD RAIL

AURORA, ELGIN & CHICAGO R.R.

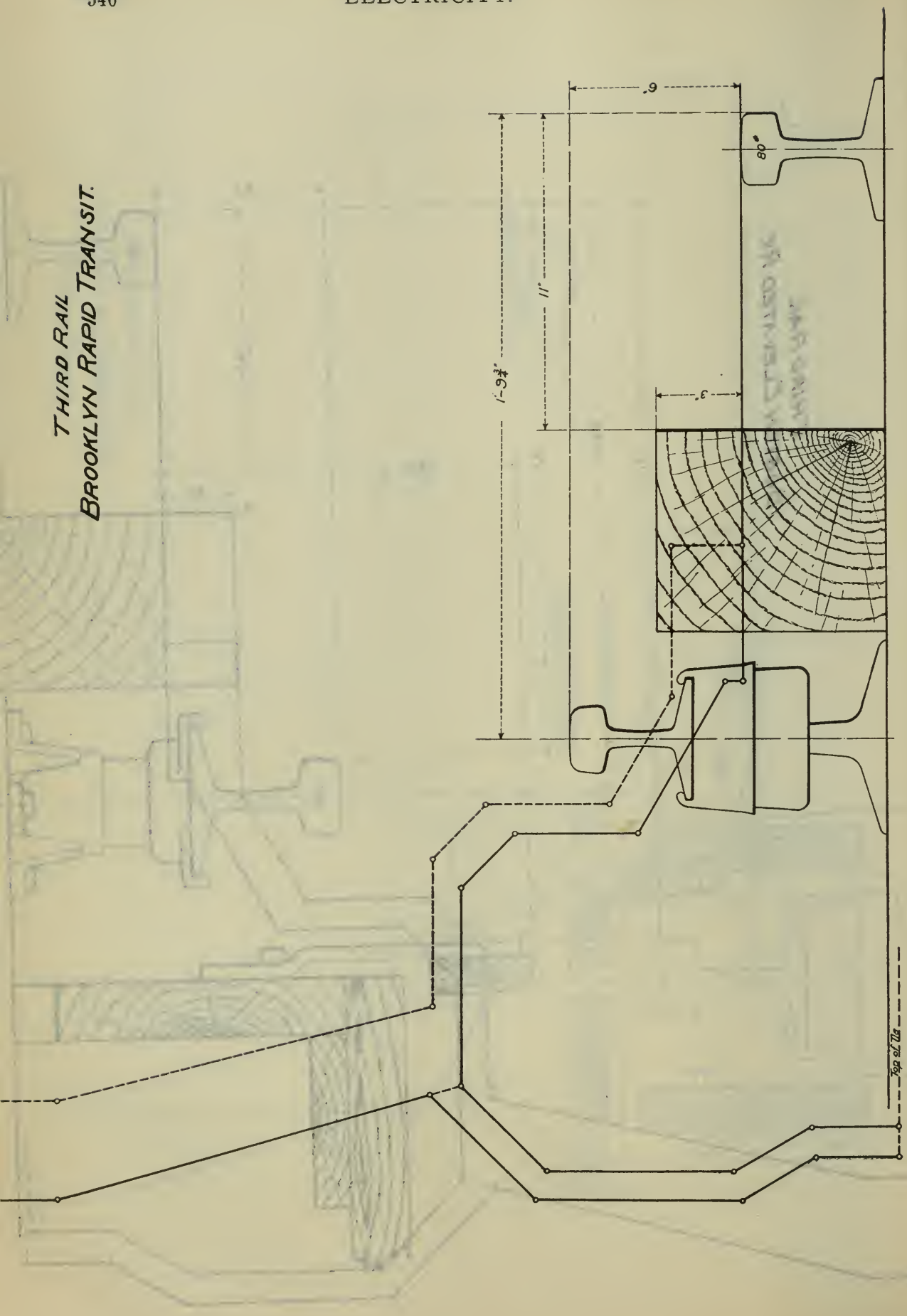
. Uses Steam Equipment



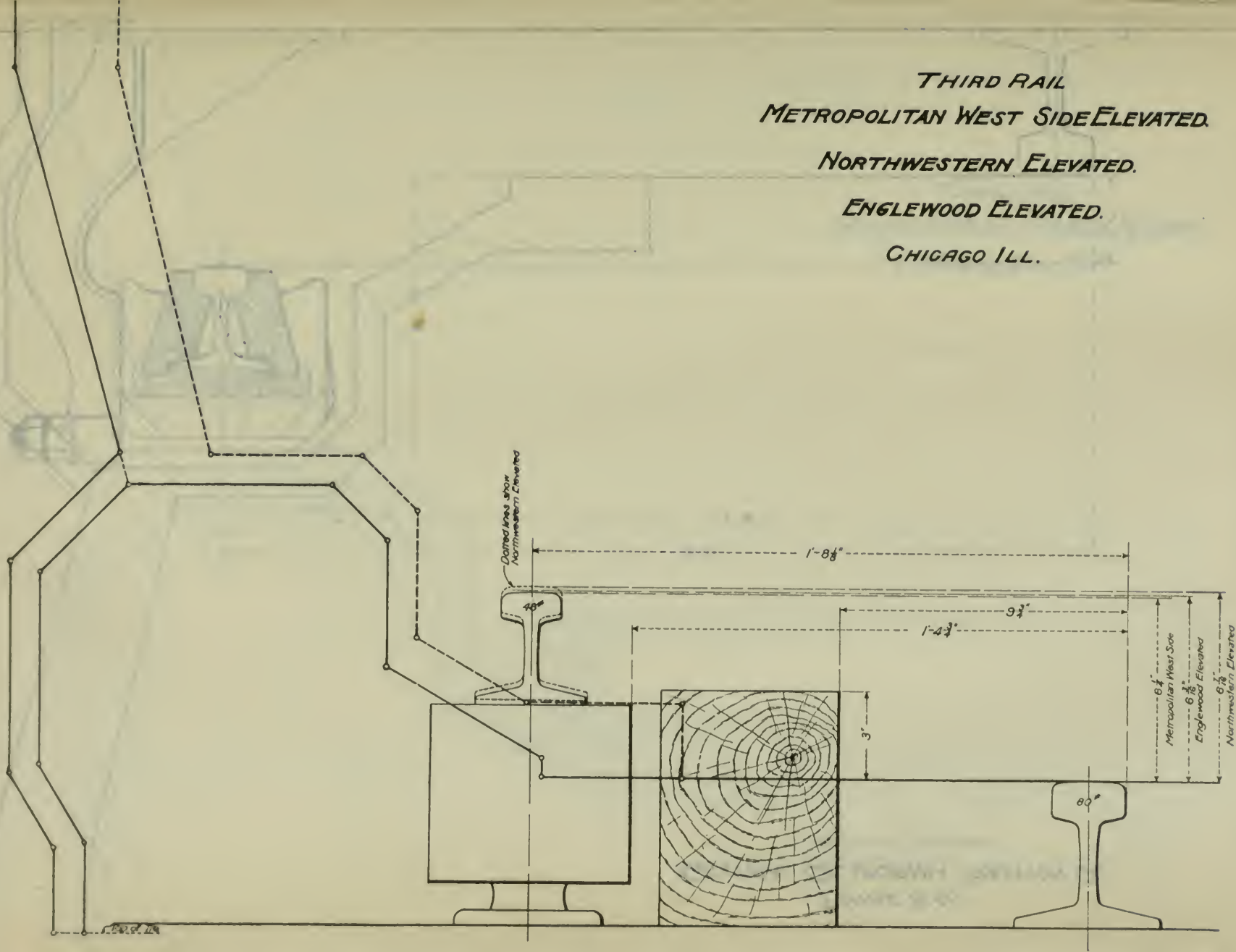

THIRD RAIL
BALTIMORE & OHIO R.R.
Uses Steam Equipment
2'-6½"
2'-1½"
2'-0½"
B & O Compound Engine Cl. E-8, E-9 with springs deflected 1½" and ties worn 1½"
With broken spring hanger Total Drop 4½"
Dotted Lines represent outline of protection at Camden & Mt. Royal Sts
B & O Equipment Clearance

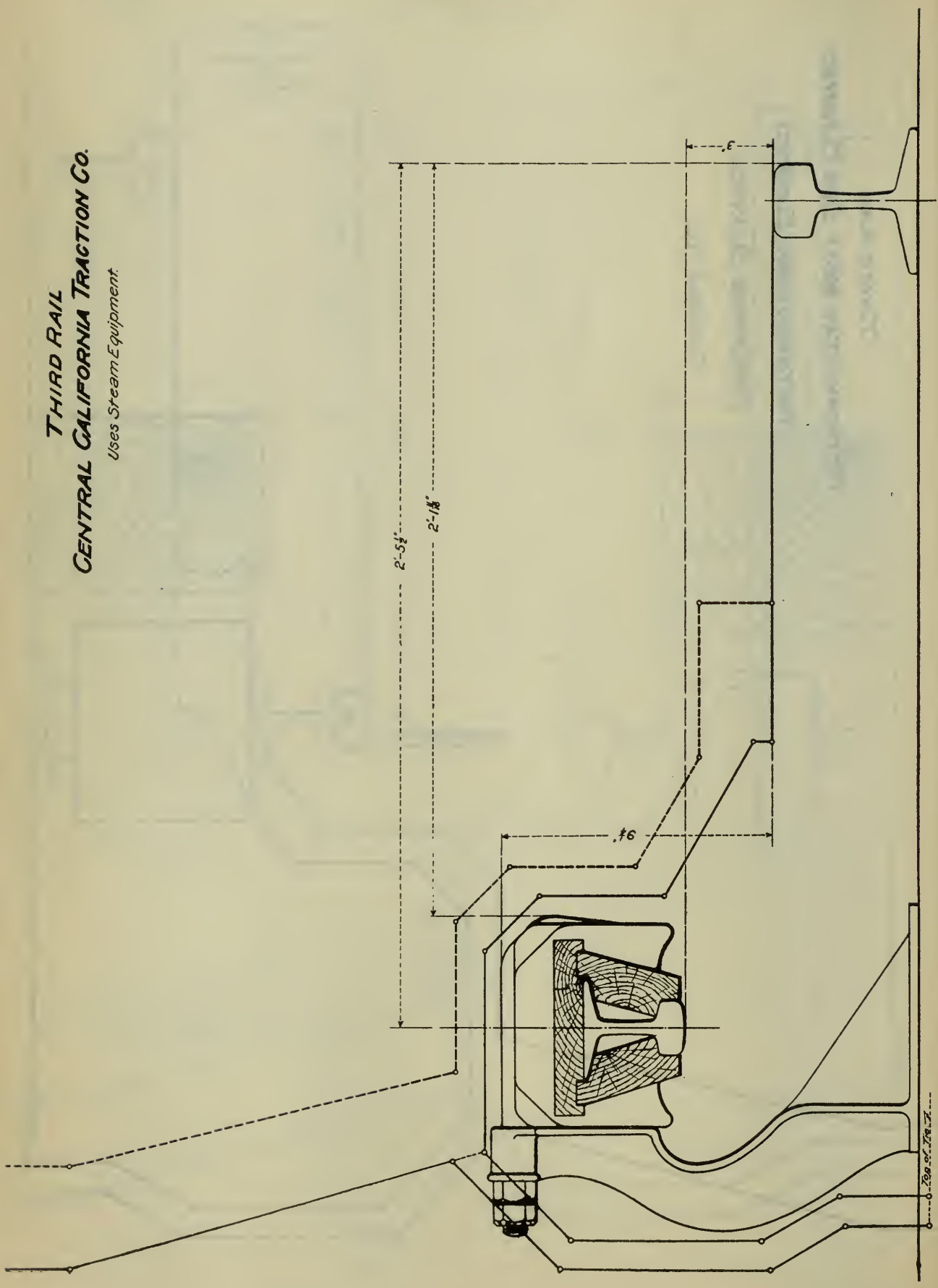

THIRD RAIL
BOSTON ELEVATED RY.
2'-1"
1'-8"
1'-7"
10-1
10½"
2½"
.65"

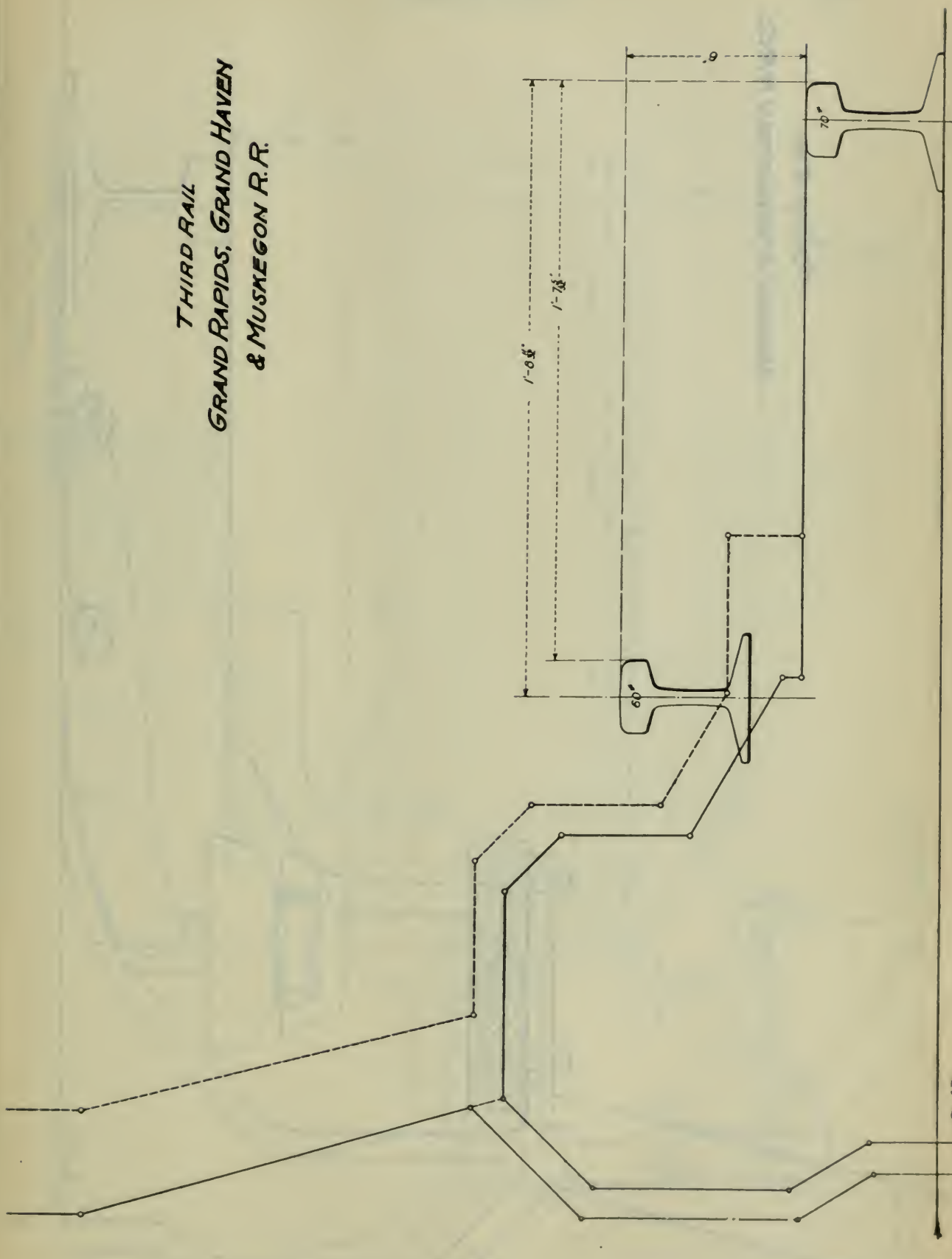
THIRD RAIL
BROOKLYN RAPID TRANSIT.

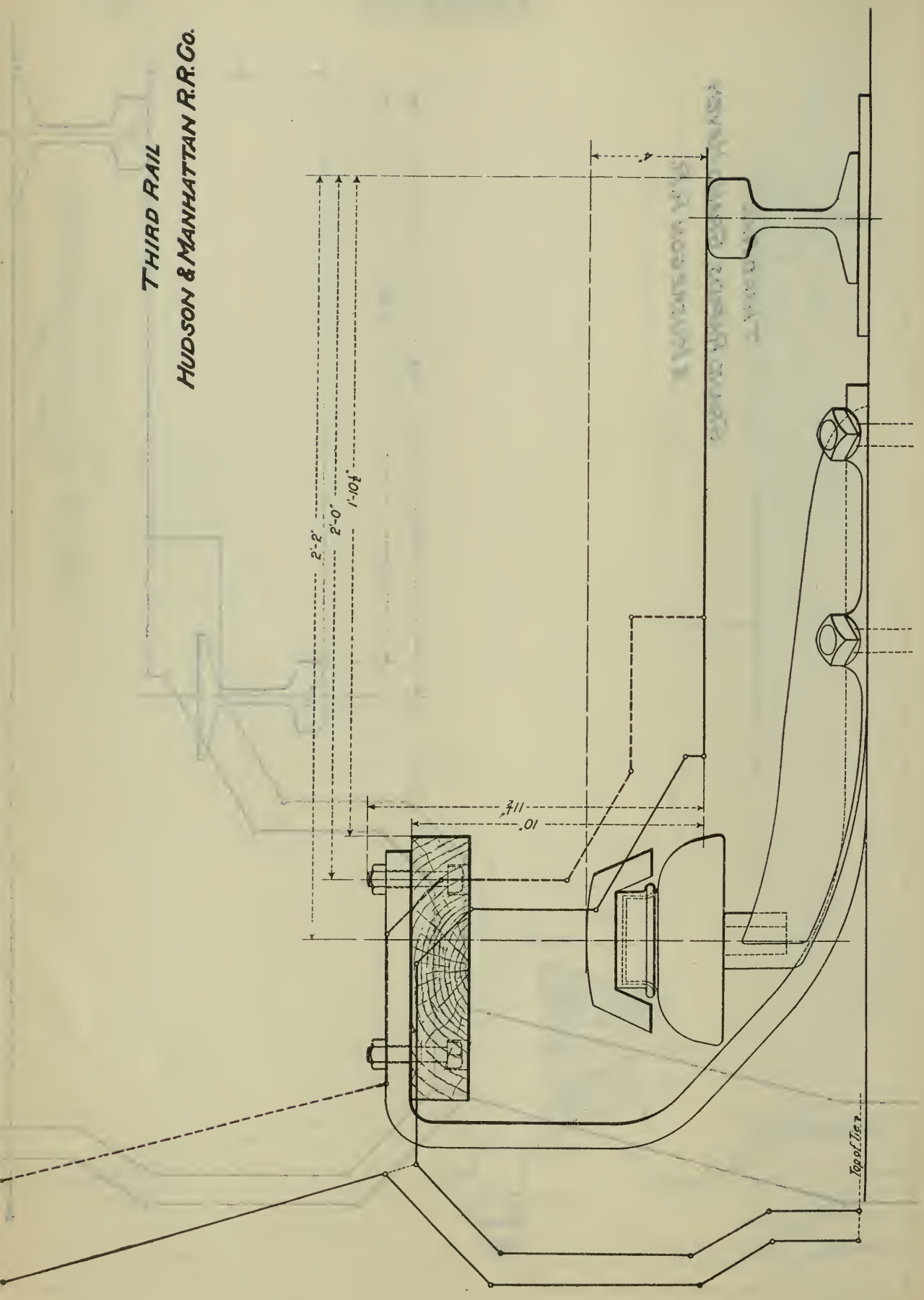


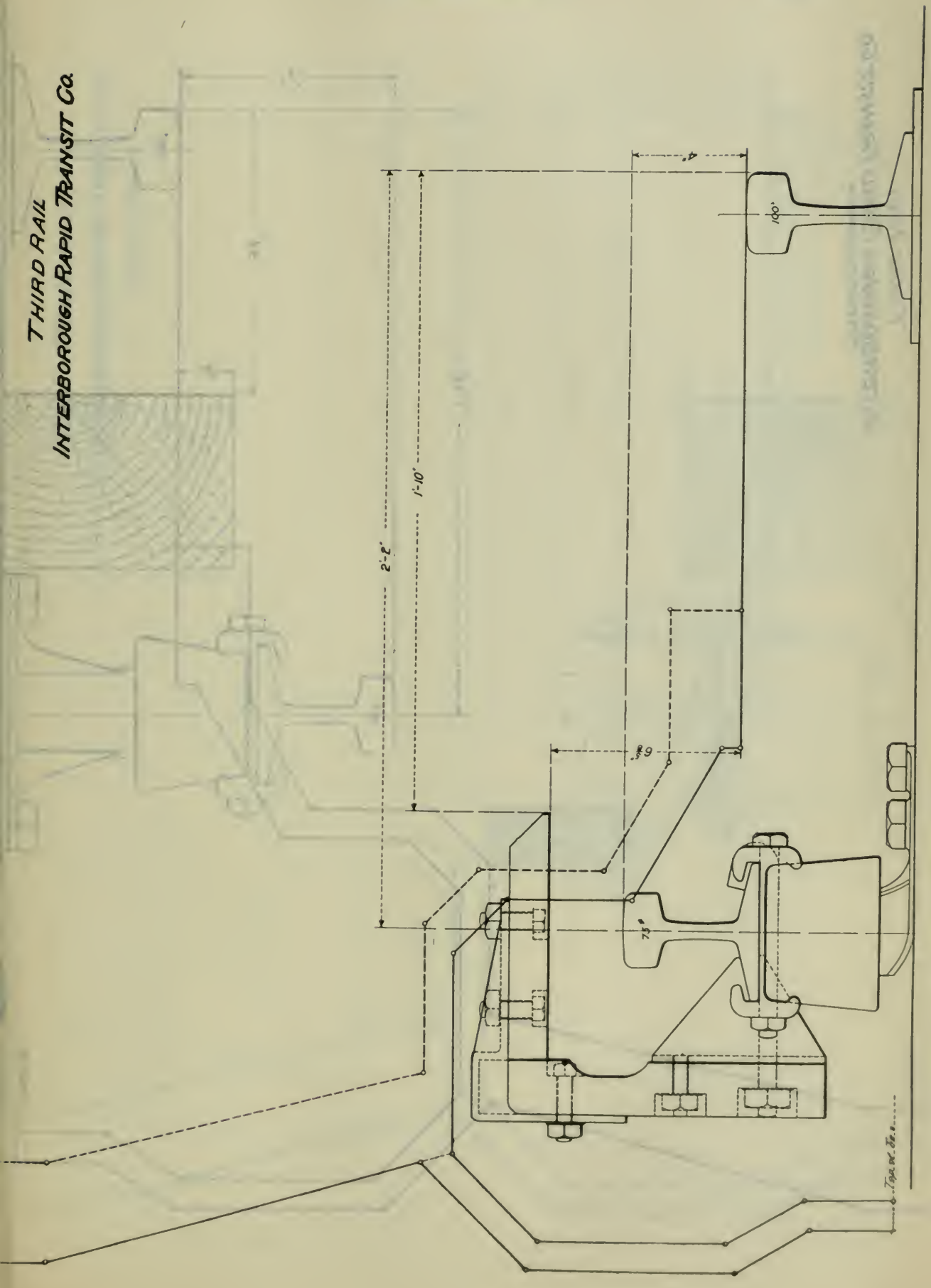
THIRD RAIL
METROPOLITAN WEST SIDE ELEVATED.
NORTHWESTERN ELEVATED.
ENGLEWOOD ELEVATED.
CHICAGO ILL.

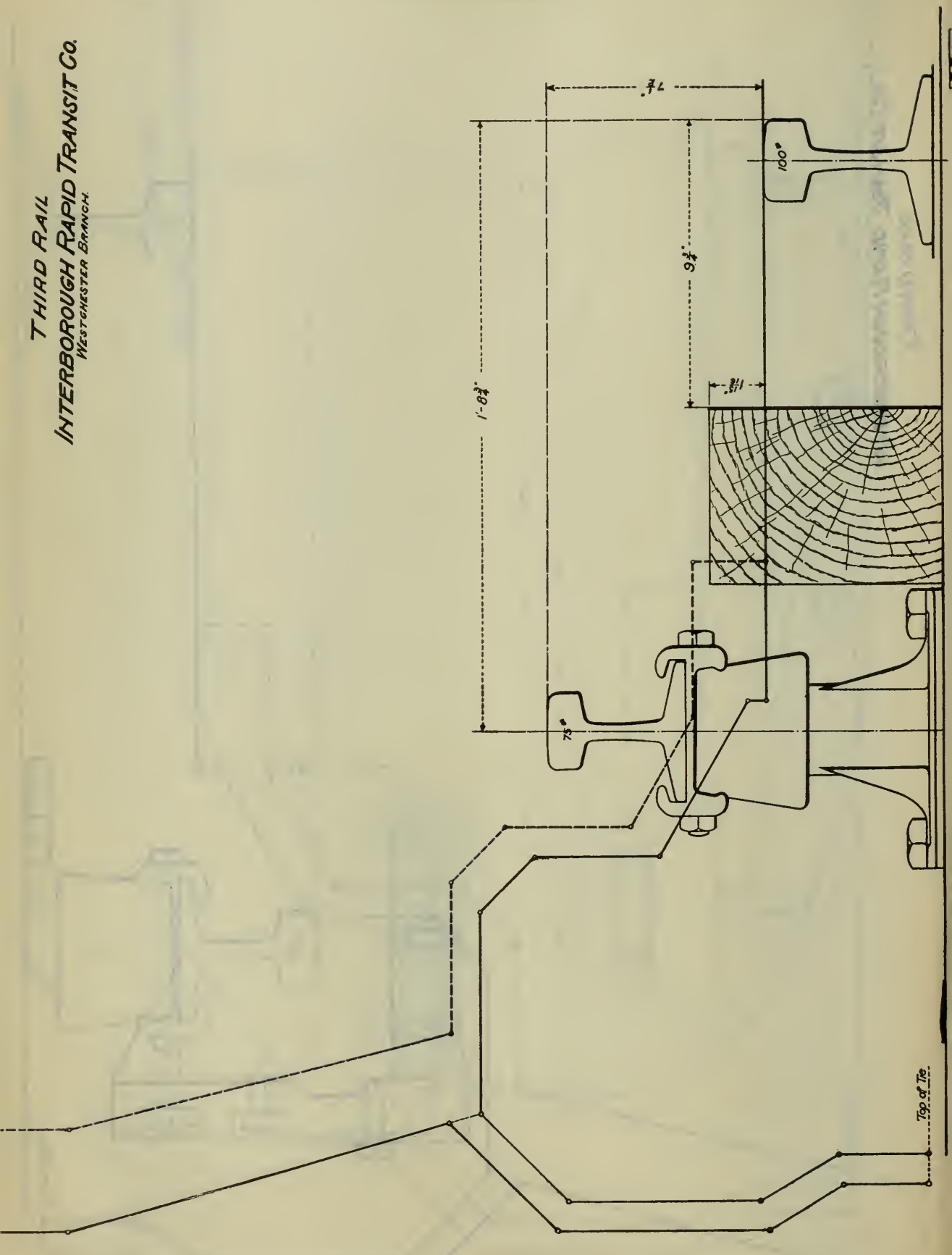


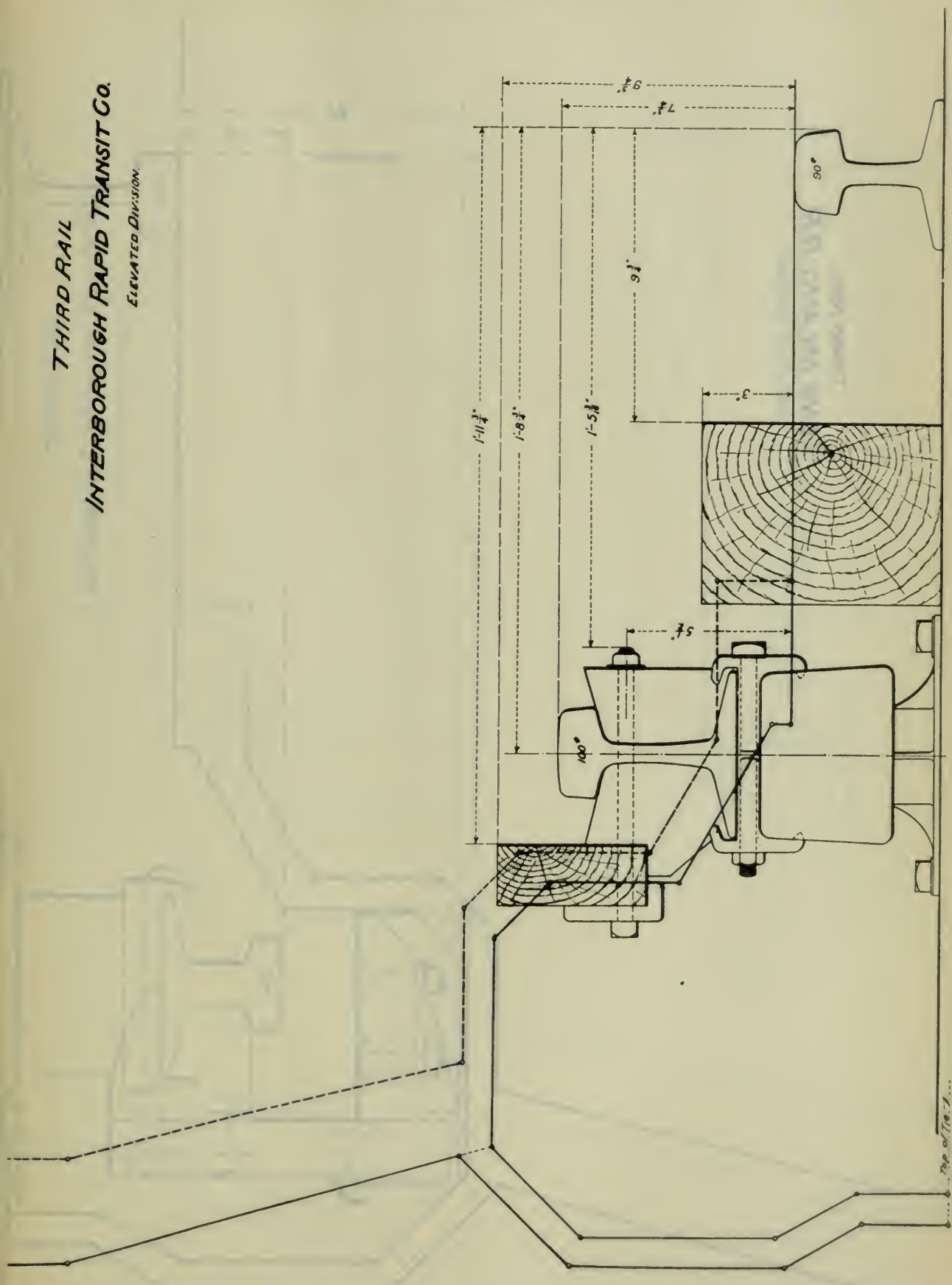

THIRD RAIL
CENTRAL CALIFORNIA TRACTION CO.
Uses Steam Equipment.
2'-5½"
2'-1⅛"
.94
.6
Top of T.R.

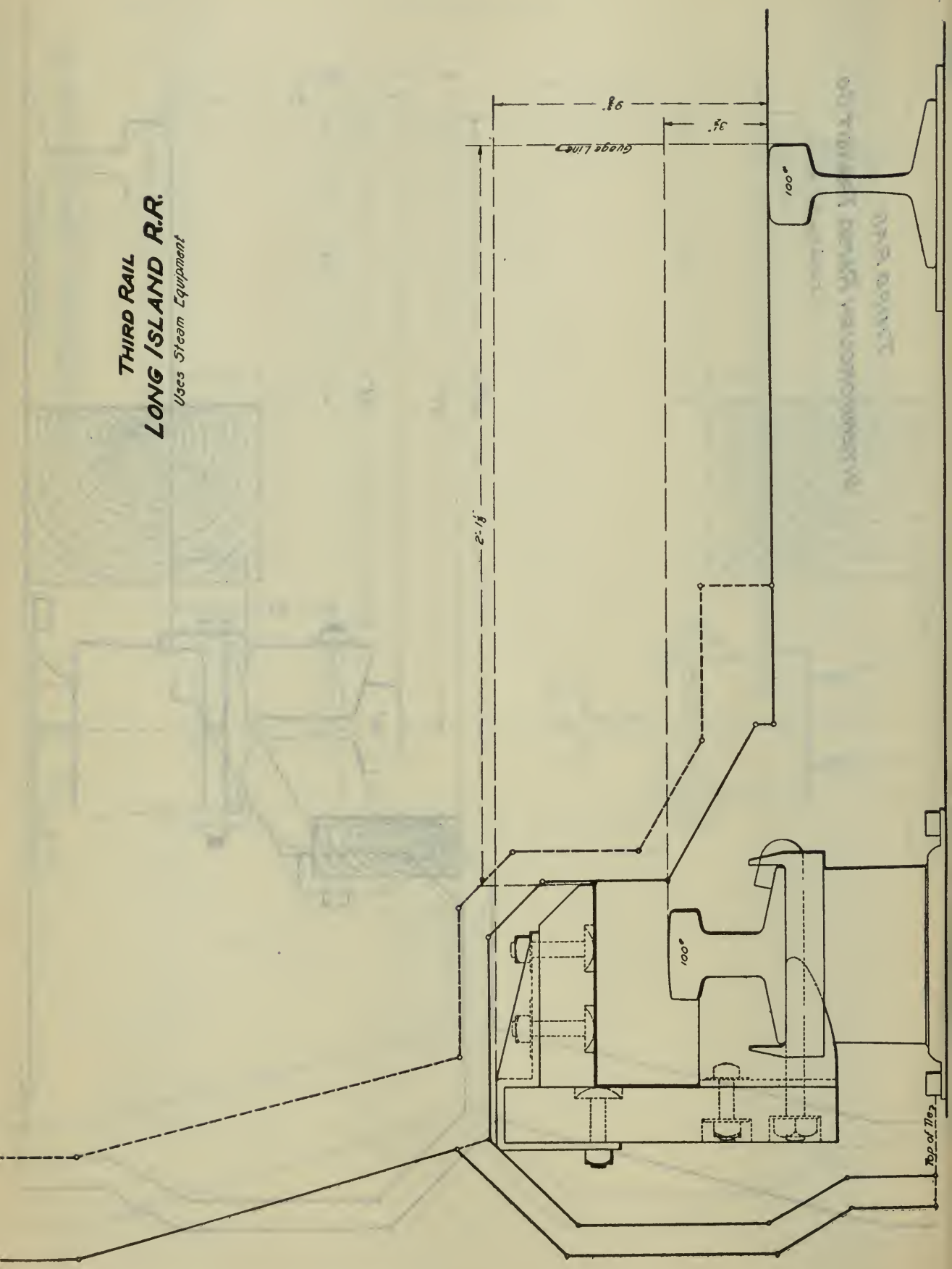

THIRD RAIL
GRAND RAPIDS, GRAND HAVEN
& MUSKEGON R.R.
.9
1'-0⅝"
1'-7⅛"
60°
70°

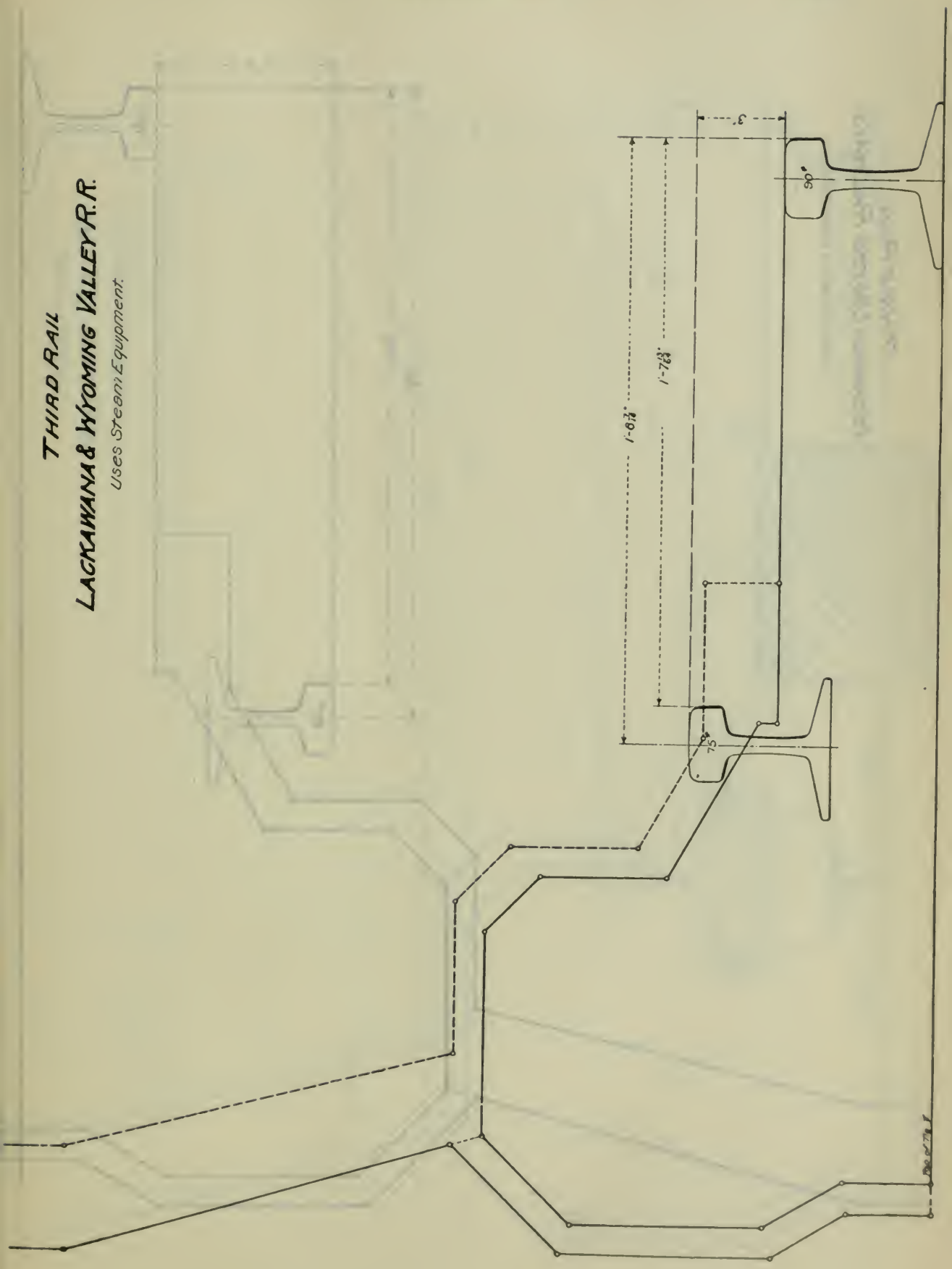

THIRD RAIL
HUDSON & MANHATTAN R.R. Co.
2'-2"
2'-0"
1'-10½"
.11
.01
Top of Tie


THIRD RAIL
INTERBOROUGH RAPID TRANSIT Co.
2'-2"
1'-10"
.89
.75"


THIRD RAIL
INTERBOROUGH RAPID TRANSIT CO.
WESTCHESTER BRANCH.
7/8"
100"
9 1/4"
1'-8 3/4"
2 1/2"
75"
Top of Tie.

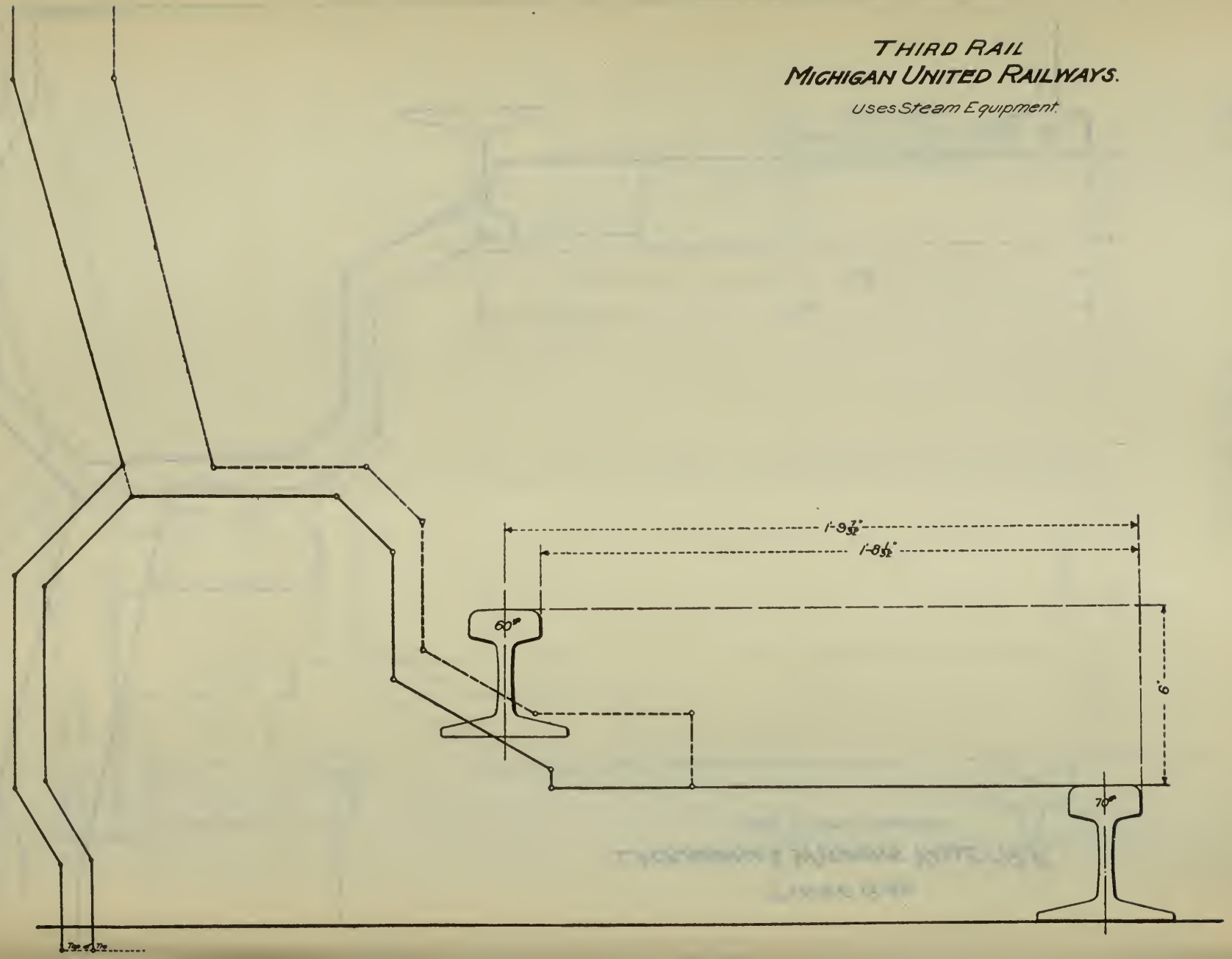

THIRD RAIL
INTERBOROUGH RAPID TRANSIT CO.
ELEVATED DIVISION.
9½"
7½"
90°
9½"
3"
1'-11½"
1'-8½"
1'-5½"
5½"
100°


THIRD RAIL
LONG ISLAND R.R.
Uses Steam Equipment
9⅛"
3½"
Gauge Lines
2'-1⅝"
100#
100#
Top of Tie


THIRD RAIL
LACKAWANA & WYOMING VALLEY R.R.
Uses Steam Equipment.
3"
90°
1'-6⅞"
1'-7⅝"
75°

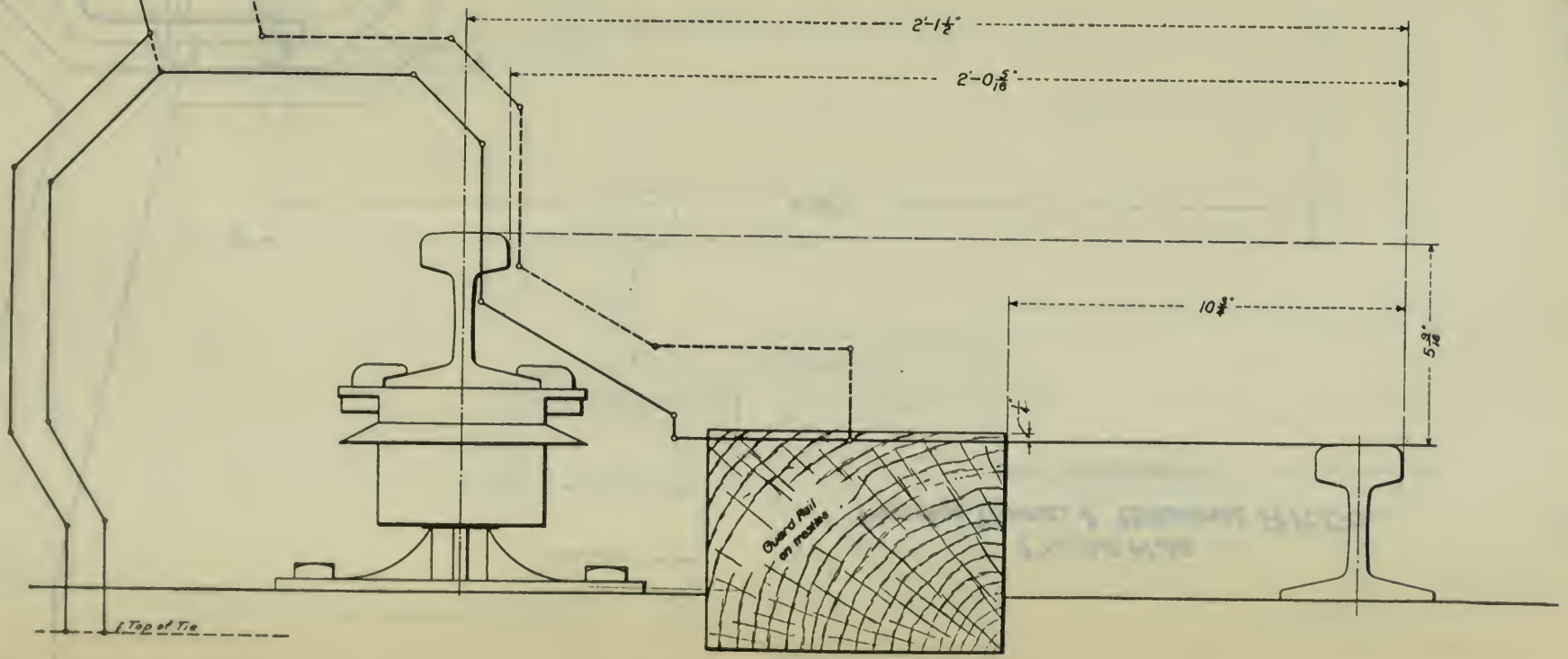
THIRD RAIL
MICHIGAN UNITED RAILWAYS.

Uses Steam Equipment.



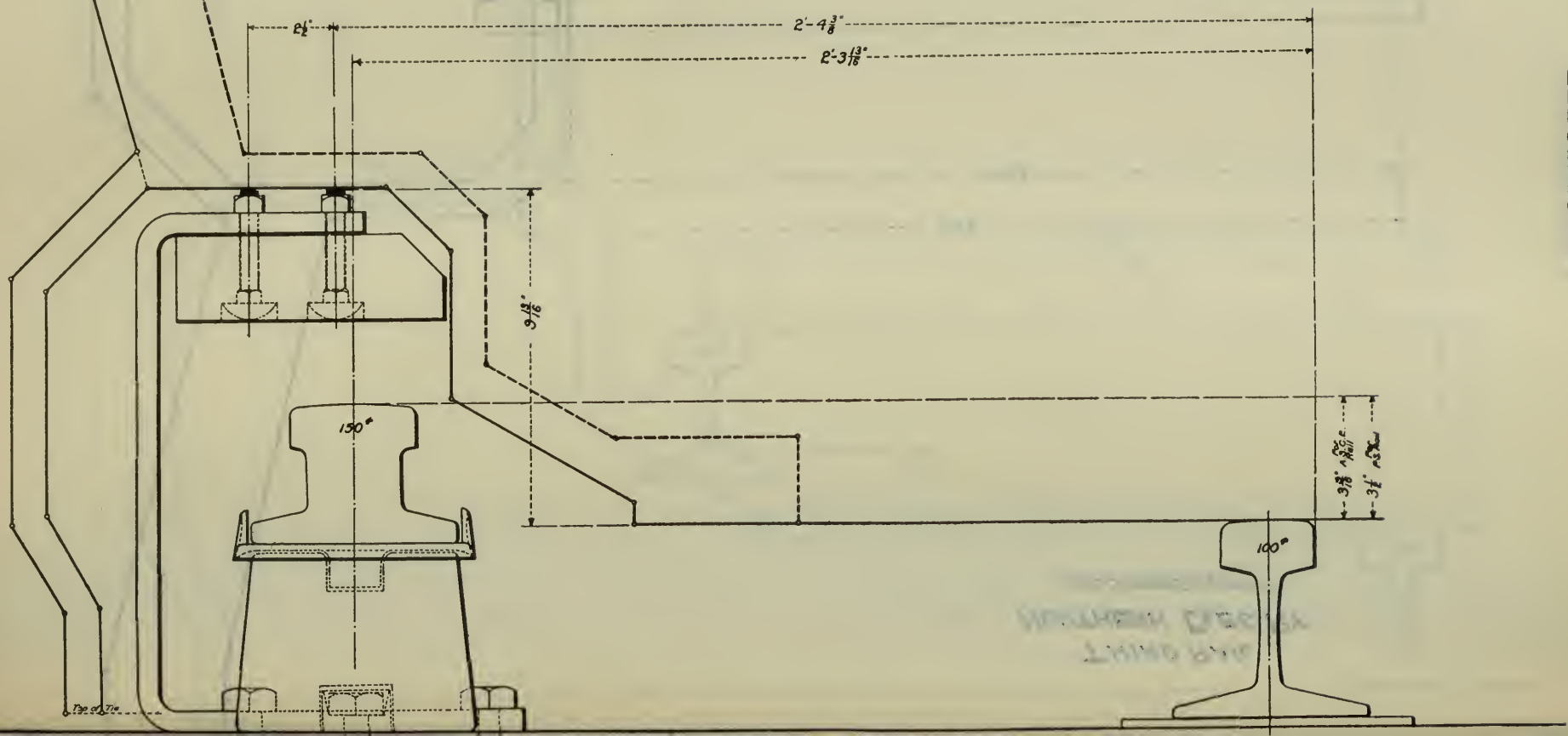
THIRD RAIL
NORTHERN ELEC. RY.

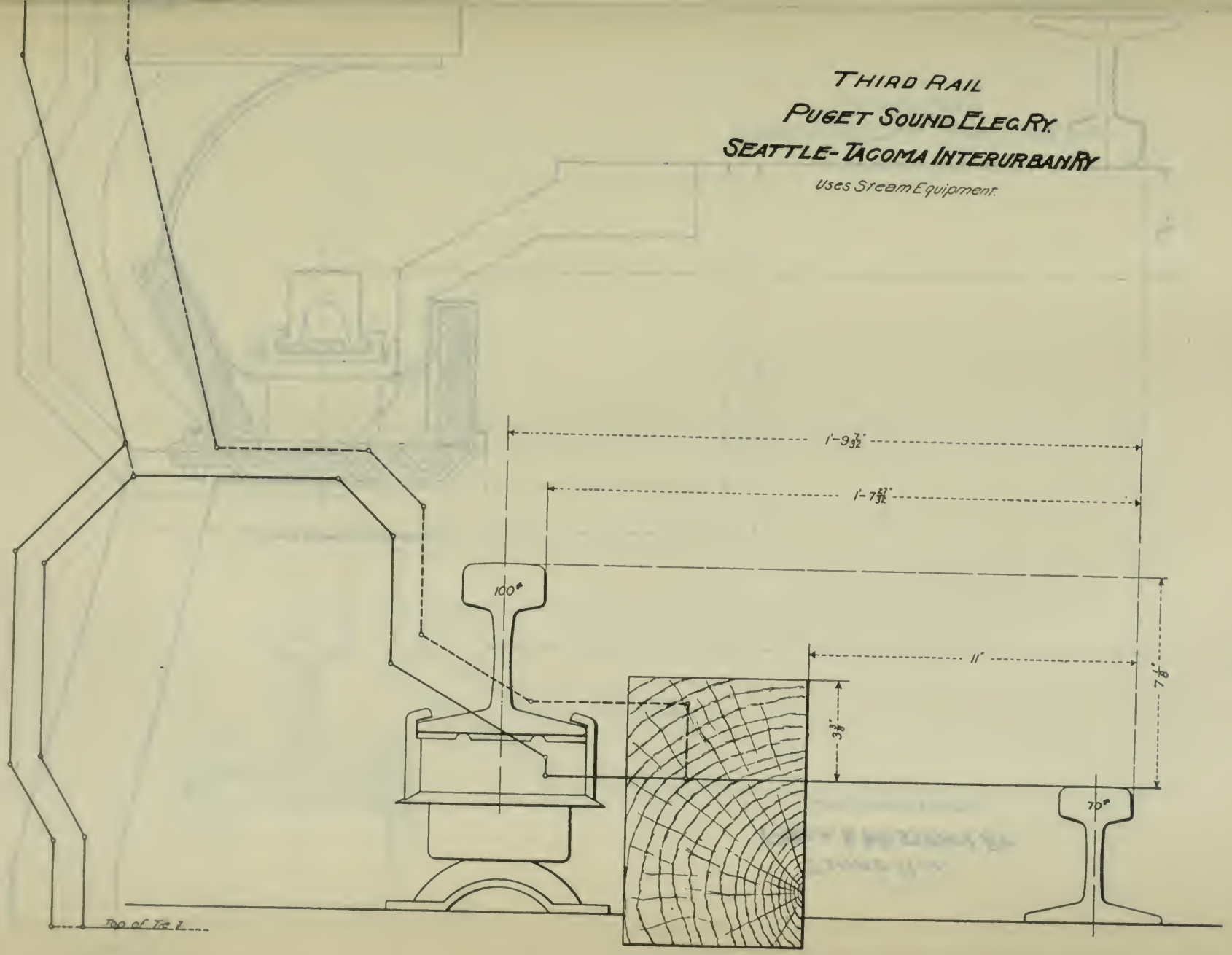
Uses Steam Equipment.

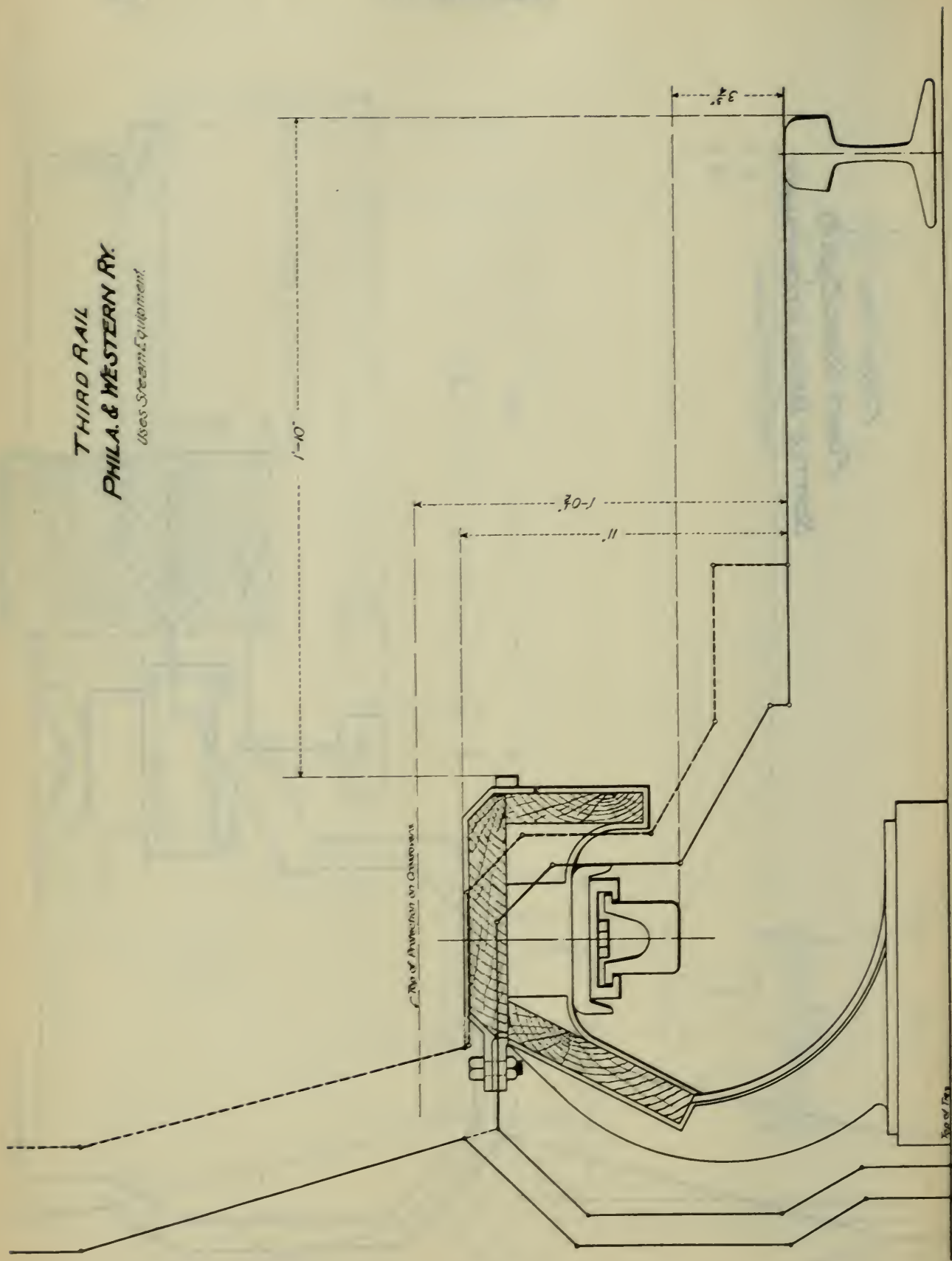


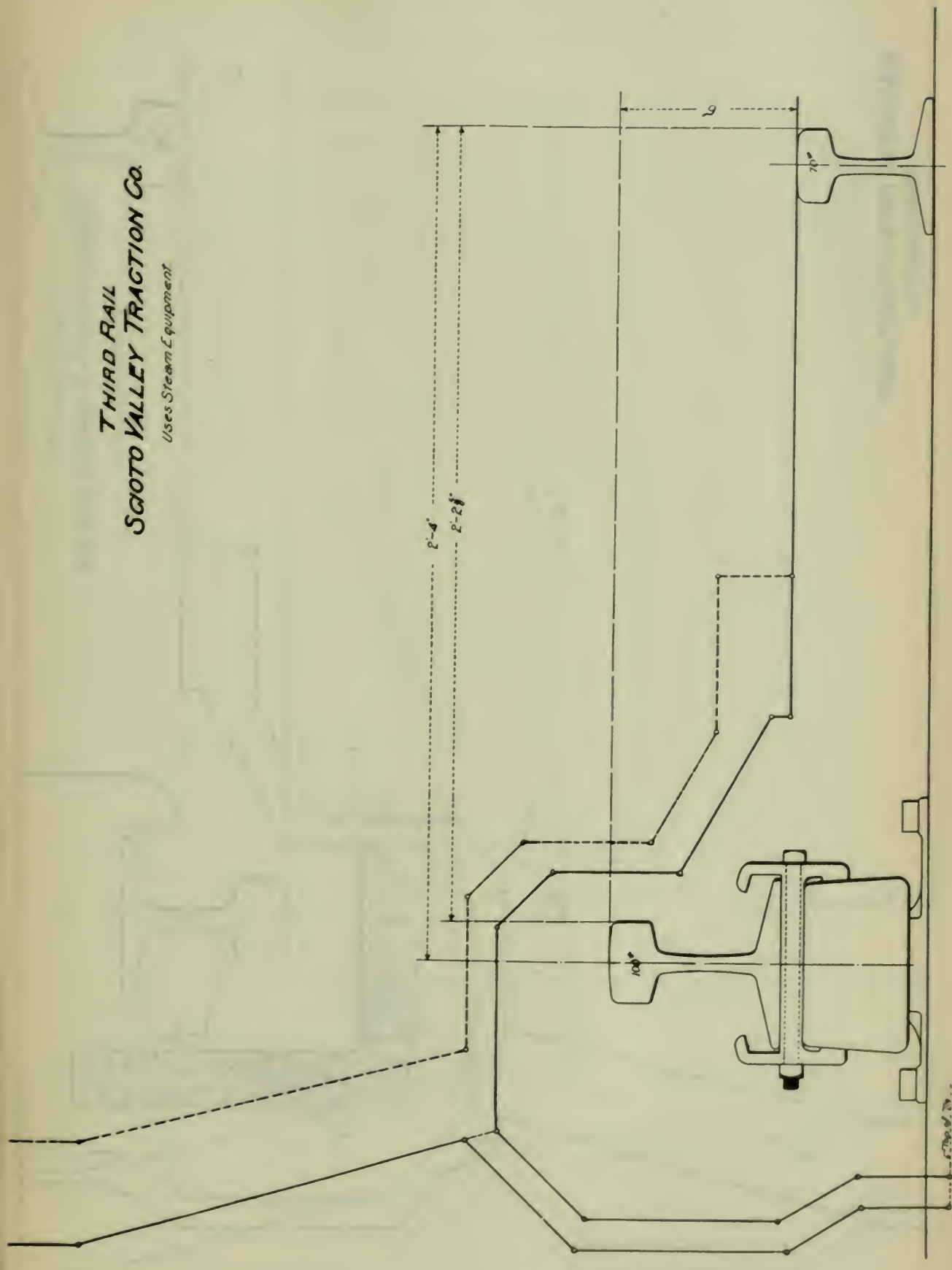
THIRD RAIL
PENNA. TUNNEL & TERMINAL R.R. CO.

Uses Steam Equipment.

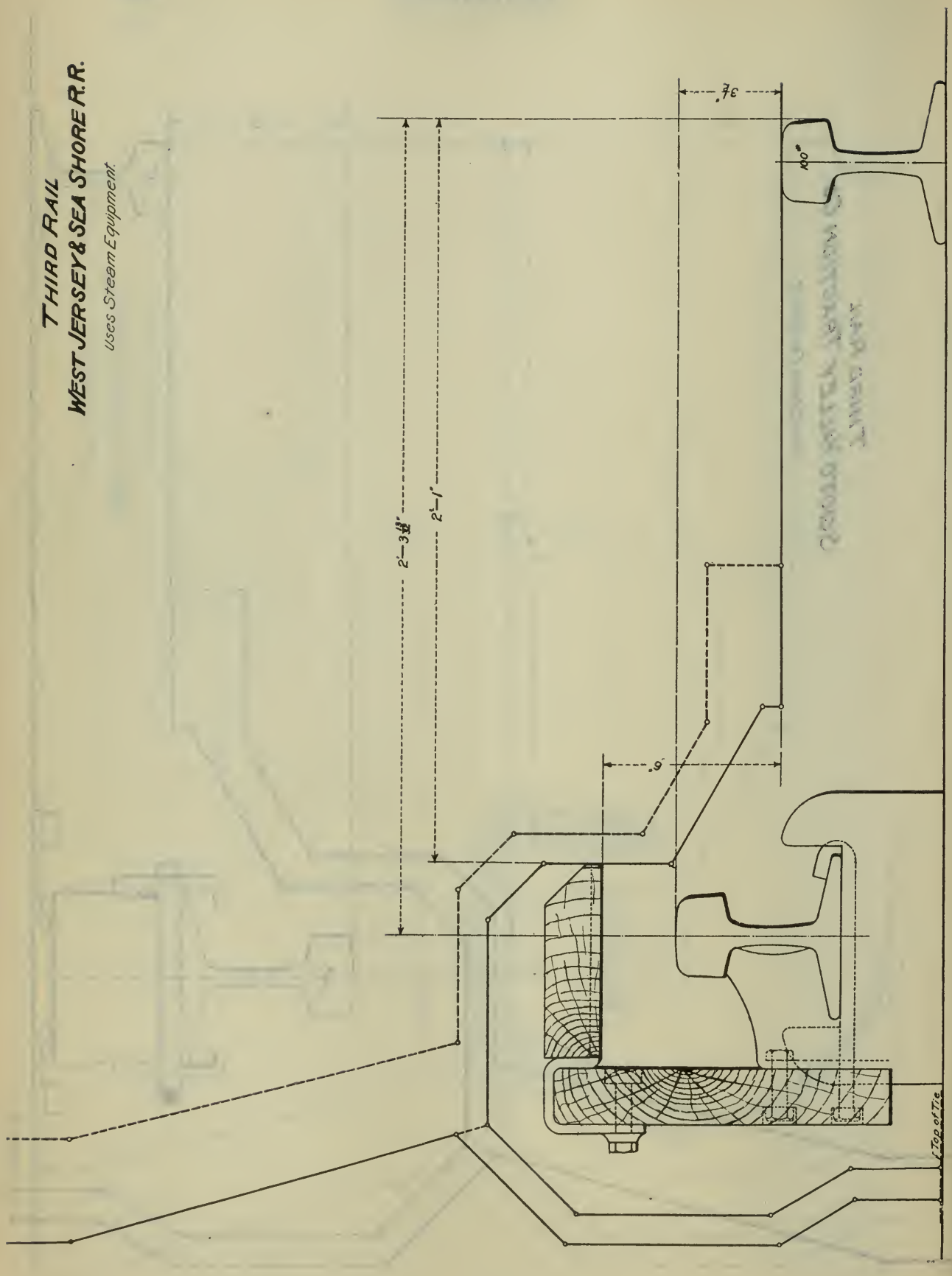



THIRD RAIL
PUGET SOUND ELEC. RY.
SEATTLE-TACOMA INTERURBAN RY
Uses Stream Equipment.
1'-9 7/32"
1'-7 27/32"
100#
11"
7.8"
3 3/8"
70#
Top of Tie L


THIRD RAIL
PHILA. & WESTERN RY.
West Steam Equipment
1'-10"
11"

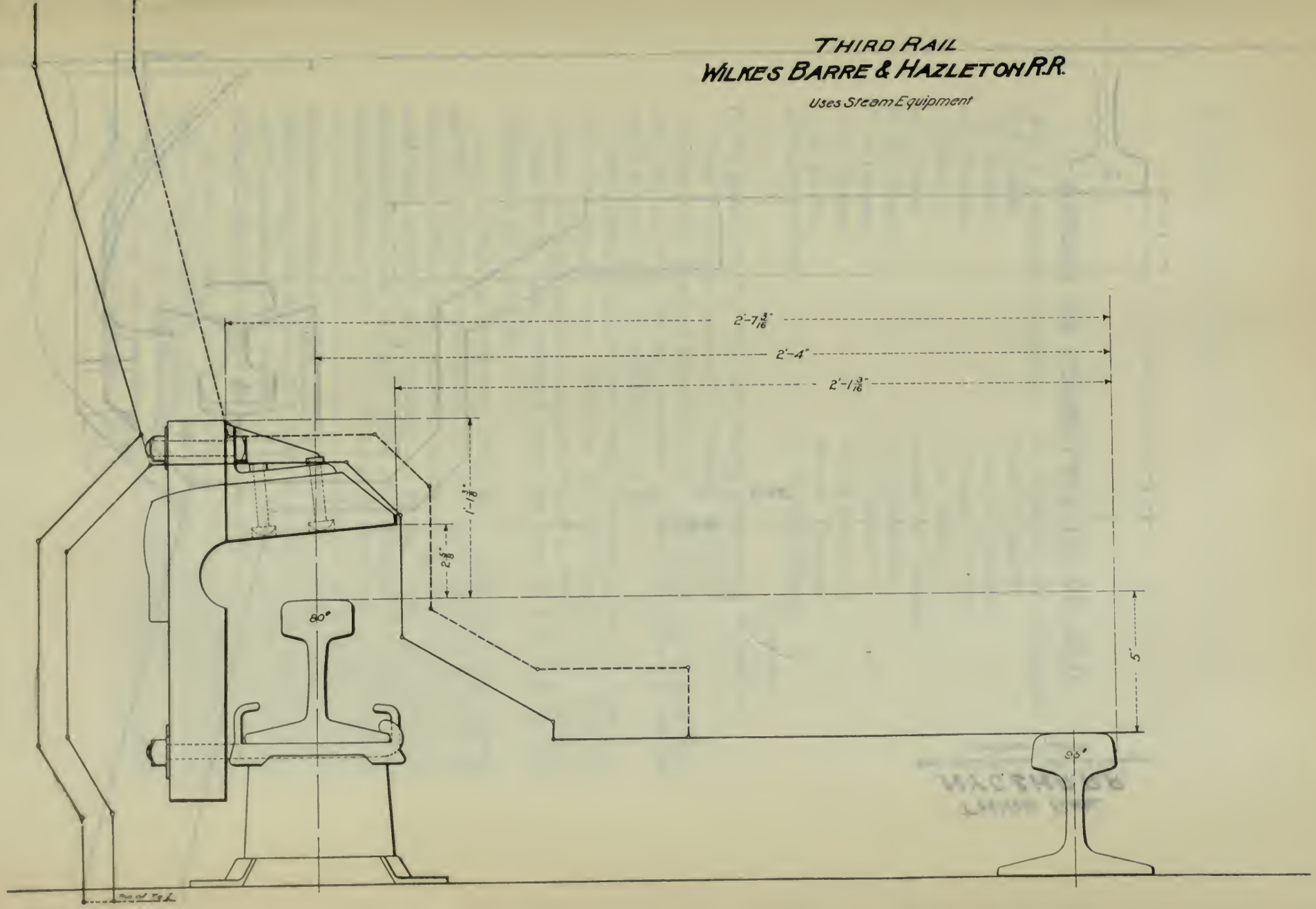

THIRD RAIL
SCIOTO VALLEY TRACTION CO.
Uses Steam Equipment
9"
7/8"
2'-4"
2'-2 1/2"
1 1/8"

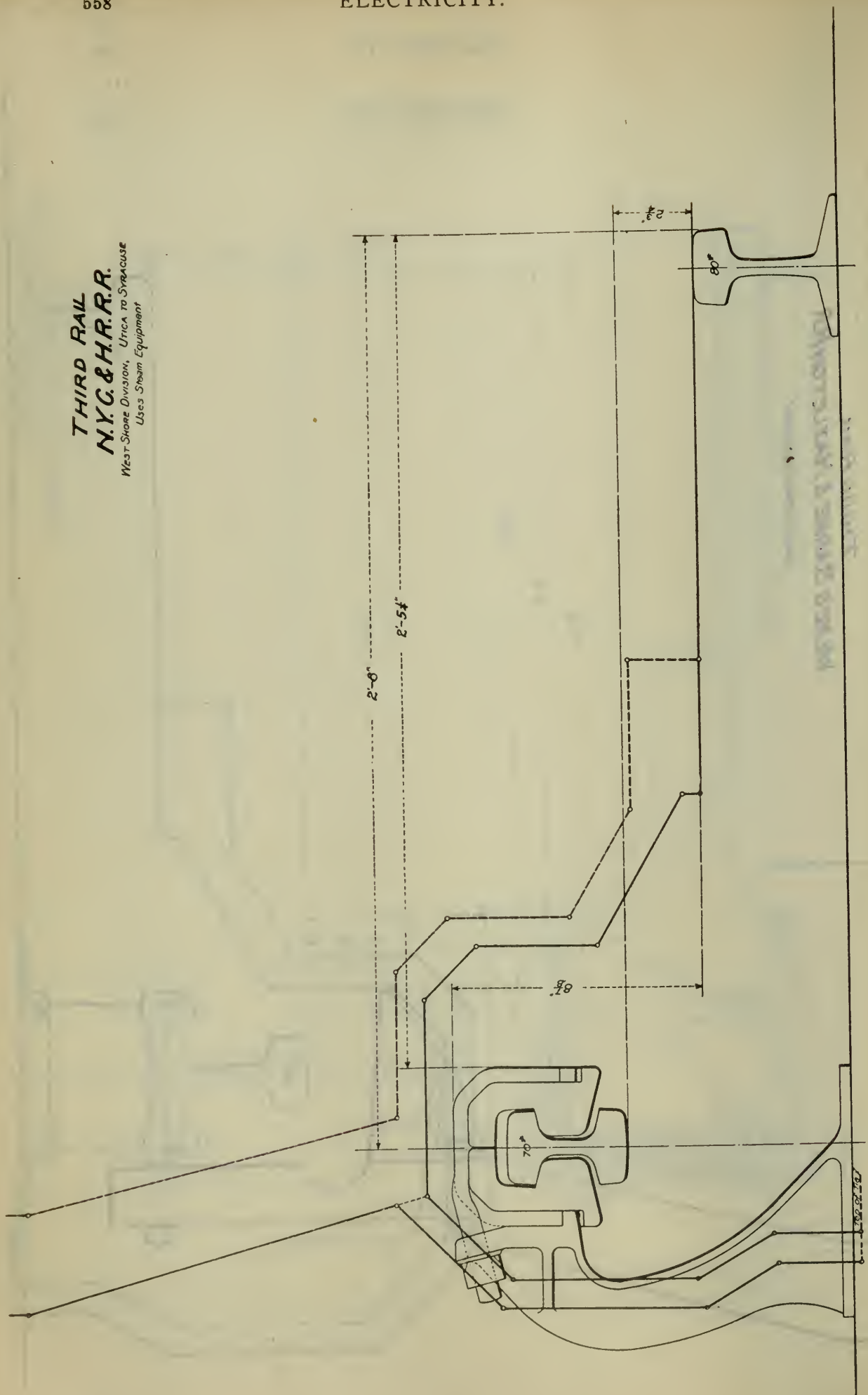
THIRD RAIL
WEST JERSEY & SEA SHORE R.R.
Uses Steam Equipment.



THIRD RAIL
WILKES BARRE & HAZLETON R.R.

Uses Steam Equipment




THIRD RAIL
N.Y.C. & H.R.R.R.
WEST SHORE DIVISION, UTICA TO SYRACUSE
USES STEAM EQUIPMENT
2'-0"
2'-5½"
2¾"
8"
8⅞"
70°

REPORT OF COMMITTEE IV—ON RAIL.

CHAS. S. CHURCHILL, *Chairman;*	R. MONTFORT, *Vice-Chairman;*
E. B. ASHBY,	JOHN D. ISAACS,
J. A. ATWOOD,	THOS. H. JOHNSON,
A. S. BALDWIN,	HOWARD G. KELLEY,
J. B. BERRY,	C. A. MORSE,
M. L. BYERS,	GEORGE W. KITTREDGE,
W. C. CUSHING,	J. T. RICHARDS
F. A. DELANO,	J. P. SNOW,
P. H. DUDLEY,	A. W. THOMPSON,
C. H. EWING,	ROBERT TRIMBLE,
C. W. HUNTINGTON,	M. H. WICKHORST,
	Committee.

To the Members of the American Railway Engineering Association:

Your Committee presents the following report:

During 1911, meetings were held at Chicago, March 20, 1911; Atlantic City, June 29, 1911; Chicago, November 14, 1911; New York, November 23 and 24, 1911; New York, February 13, 1912.

At the meetings held in New York, November 23 and 24, representatives of the Manufacturers' Committee were also present. In addition to the above meetings, several meetings of the Sub-Committees were also held.

Reports have been submitted during the year, as a part of the Rail Committee's work, as follows:

(A) A Study of Seventeen Good Service Rails, by Robert Trimble and W. C. Cushing (Bulletin No. 135, May, 1911), with notes by M. H. Wickhorst. These rails contained carbon within or a little above the usual limit for 85-lb. rails, namely, 0.45 to 0.55. With this carbon the phosphorus was close to 0.10 or above, the manganese was mostly within the usual limits of 0.80 to 1.10. Some of the rails were of fairly uniform composition throughout the section as indicated by the etching, but others were more or less segregated. This study did not perhaps lead to any very definite results, but indicates that under some conditions segregated rails high in phosphorus, and possibly also in carbon, may give long service, although it does not define these conditions either of track or material.

(B and C) Rail Failure Statistics for the Year Ending October 31, 1910, and Segregation and Other Rail Proprties as Influenced by the Size of Ingot, by M. H. Wickhorst (Bulletin No. 137, July, 1911).

Mr. Cushing made a study of the Rail Failure Statistics and below are his comments on the subject:

(1) Study of these general statistics does not furnish accurate and specific information so as to determine the value of different sections of rail, because:

(a) The conditions of traffic are different.

(b) The conditions of roadbed are different.

(c) The conditions of ingot making and rolling practice are so different that the quality of the material varies widely, and, at the present time, this difference in quality of the material eliminates differences in section; nevertheless, when the time comes that the difference in quality of material will be less, the influence of the section will be more apparent, for there is no doubt that one section is stiffer and stronger than another according to the distribution of the material. Inasmuch as we are endeavoring to eliminate the differences in quality of material and bring it to a high state of perfection, we should not, in the meantime, lose sight of the desirable features of the rail section, but keep them constantly in mind, so that when we arrive at a good quality of metal, we will also have a desirable rail section.

(2) A study of these general statistics tends to disclose unusual results, and were it not for their compilation, we would not have much information relative to the difference between Bessemer and Open-Hearth steel and concerning the various alloys.

(3) The general statistics are also important, in showing a relation between broken rails and failure of head, web and base.

(4) Their tabulation discloses the difference between Steel Companies when the sections and chemical composition are practically the same.

The report by Mr. Wickhorst covers an investigation made at the South Works of the Illinois Steel Company, to throw light on the relationship of the size of ingots of Bessemer Rail steel to the segregation of the metalloids, locations of pipes and blow holes, and the properties of the rails. This investigation showed that under the conditions of the tests, the carbon, phosphorus and sulphur collected or segregated toward the interior and upper part of the ingot and that, in a general way, such segregation increased as the size of the ingot increased. The manganese also segregated some, but to a much smaller extent, while the silicon showed little or no tendency to segregate.

The elements which segregated as described also showed a lowering in the top part of the ingot, below the average composition of the steel, and this lowering extended downward along the sides of the ingot. The "negative" segregation increased in general as the size of the ingot increased and also extended down further along the sides of the ingot. There was also a region of negative segregation in the interior and lower part of the ingot, but the lowering of the elements was not as great in this region.

This investigation also indicated that the material was distributed in

the rail bar about the same, relatively, as it was in the ingot from which the rail bar had been rolled.

(D) Tests of Rail Steel Ingots and Derivative Shapes Made at Watertown Arsenal, being a Review by M. H. Wickhorst of the Report Published by the Watertown Arsenal (Bulletin No. 139, September, 1911).

This report covers a digest and analysis of the Government investigation at the Watertown Arsenal of rail steel ingots and derivative shapes as embodied in the Report of Tests of Metals, etc., made at the Watertown Arsenal for the year 1909.

The work indicated that the interior cavities of an ingot cooled directly after pouring are about the same or slightly less than in a similar ingot placed in the soaking pit and then cooled. This same result was also indicated as true of blooms made from such ingots.

It was shown that almost the full tensile strength and ductility of the metal of the lower part of the ingot were obtained rolling to about one-tenth of the original cross-section, but with the metal of the upper part of the ingot it was necessary to reduce the cross-section to one-twenty-fifth or less of the original amount.

A great many etchings were made and it was shown that the structure of the cross-section as developed by etching varies from the top to the bottom of the ingot and that each structure finds its counterpart in succeeding shapes and at about the same proportionate distance from the top end. It was also shown that the structure was considerably altered by changing the position in which the ingot was allowed to cool, as for instance allowing it to cool on its side after stripping.

(E) Influence of Rolling Temperature on the Properties of Bessemer Rails, by M. H. Wickhorst, November, 1911.

This report covers an investigation made at the works of the Carnegie Steel Company to determine the influence of the temperature of rolling on the properties of Bessemer Rails. This work indicated that the ductility and deflection in the drop test were influenced little, if any, by the rolling temperature. The number of blows that it took to break the rails in the drop test was uninfluenced by the temperature of rolling. The yield point and tensile strength in the tension tests were influenced little, if any. The elongation in the tension test decreased some as the temperature increased. The influence of temperature showed most prominently in the tension test, in the reduction of area, which decreased as the temperature of rolling increased. The size of the grain, as shown by the microscope, increased as the temperature increased.

In this report it is also pointed out that the ductility in the drop test with the head of the rail in tension more nearly indicates the ductility of the interior metal as measured in the tension test, than does the ductility in the drop test with the base of the rail in tension, which is usual in inspection work.

Each report mentioned above gives a short summary of the matter

contained in it, but the main principles that seem to have been brought out by the year's work are brought out in the brief reviews above.

The general plan of our research work during the year has been to direct attention to some one item which enters as a factor in the properties of the finished rail and attempt to obtain definite information concerning its influence by the experimental method of obtaining as great a range as practicable in the one item under consideration, but leaving all other conditions as near alike as obtainable in the several experiments. It is thus hoped to establish in the course of time the metallurgical principles and laws that apply to the manufacture of steel rails.

(1) The first item of work for the Rail Committee according to the instructions for 1911, was to recommend changes in the specifications for steel rails.

Considerable work has been done during the past year in the preparation of specifications, and the specifications submitted herewith are recommended by your Committee. Some paragraphs, such as Nos. 5, 6, 14 and 15, are not to be considered as final, it being thought that the Committee did not have sufficient information in its possession to make these sections in the specifications mandatory.

One of the sections in question, No. 14, refers to the ductility test.

The requirements, in the specifications, for ductility are somewhat lower than some members of your Committee think desirable, and it is hoped that sufficient information will be obtained during the coming year to enable the Committee to make some revision in these respects.

Paragraph No. 15, referring to deflections as a method of classifying rails, is also tentative. It is the intention when sufficient data is at hand to prescribe maximum and minimum limits for deflections under the drop test.

(2) Present recommendations on standard rail sections.

The Committee reports progress.

(3) Continue investigation of the breakage and failure of rails and present summary of conclusions drawn from reports received.

Bulletin No. 137, July, 1911, contains the rail failure statistics for the year ending October 31, 1910, and the conclusions in regard to the matter are presented in that report.

(4) Report on the results obtained from the use of Open-Hearth and Special Alloy Steel Rails, and the Chemical Composition of such rails.

Bulletin No. 137, referred to above, containing the report of the rail failure statistics, also gives all the information that the Committee has in regard to Open-Hearth and Special Alloy Steel Rails.

In regard to the remaining part of the outline of work for the year 1911, the Committee reports no progress.

The Committee desires to call attention to the valuable services rendered by Mr. M. H. Wickhorst, Engineer of Tests, for the Committee.

Mr. Wickhorst has succeeded in winning the confidence of the Manufacturers and has thereby succeeded in securing their co-operation in the work which is being done. Considerable light has been thrown upon the subject by these investigations of Mr. Wickhorst, and it is hoped that in the future considerable good will be accomplished as a result of the investigations.

Your Committee desires to acknowledge the very generous manner in which the various Rail Manufacturers have offered us the material and facilities of their mills to carry on this research work. The condition of co-operation that we are working under is very gratifying and, it would seem, must work toward the best interests of the railroads, the steel mills and the general public.

The Committee recommends the following lines for investigation during the coming year:

(1) Recommend changes in specifications for steel rails.

(2) Present recommendations on standard rail sections.

(3) Continue investigation of the breakage and failure of rails and present summary of conclusions drawn from reports received.

(4) Report on the results obtained from the use of Open-Hearth and Special Alloy Steel Rails, and the Chemical Composition of such rails.

(5) Present reports on the results of tests made on the various kinds of rail in conjunction with the Manufacturers' Committee on the revolving machine at South Chicago.

(6) Report on standard drilling for rails.

Special Investigations by Mr. Wickhorst.

(1) Test Open-Hearth Steel in ingots of various sizes.

(2) Influence of height of ingot with usual cross-section—

(a) Bessemer Steel;

(b) Open-Hearth Steel.

(3) Influence of temperature of rolling on high carbon Open-Hearth steel.

(4) Drop Tests. Influence of temperature of test piece on ductility and deflection in drop test.

(5) Tests with reciprocating machine, especially to determine influence of interior segregation.

(6) Influence of Titanium—

(a) Bessemer Steel;

(b) Open-Hearth Steel.

(7) Influence of thickness of mold on segregation and cavities, cast in sand and in molds of various thickness—

(a) Bessemer Steel;

(b) Open-Hearth Steel.

(8) Influence of methods of cooling on the cooling beds, especially with high carbon steels; also the effects of cold straightening.

(9) Influence of the temperature of the liquid steel when poured into molds.

(10) Experiments with methods of casting ingots for improvements as regards blow holes, pipes, etc.

(11) Drop Tests, Permanent Set, Ductility, etc.

(a) Influence of carbon.

(b) Influence of phosphorus.

(c) Influence of manganese.

(d) Influence of span of supports.

(e) Influence of moment of inertia.

Respectfully submitted,

COMMITTEE ON RAIL.

AMERICAN RAILWAY ENGINEERING ASSOCIATION.

SPECIFICATIONS FOR CARBON STEEL RAILS.

1912.

INSPECTION.

Access to Works.

1. Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while the contract is being executed, and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the rails have been made in accordance with the terms of the specifications.

Place for Tests.

2. All tests and inspections shall be made at the place of manufacture, prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the mill.

MATERIAL.

Material.

3. The material shall be steel made by the Bessemer or Open-Hearth process provided by the contract.

CHEMICAL REQUIREMENTS.

Chemical Composition.

4. The chemical composition of the steel from which the rails are rolled, determined as prescribed in Section 7, shall be within the following limits:

Elements	For Bessemer Process		For Open-Hearth Process	
	70 lbs. and over, but under 85 lbs.	85 - 100 lbs. inclusive	70 lbs. and over, but under 85 lbs.	85 - 100 lbs. inclusive
Carbon	0.40 to 0.50	0.45 to 0.55	0.53 to 0.66	0.63 to 0 76
Manganese	0.80 to 1.10	0.80 to 1.10	0.60 to 0.90	0.60 to 0 90
Silicon not to exceed	0 20	0.20	0.20	0 20
Phosphorus not to exceed	0.10	0.10	0.04	0.04

Modification of Carbon for Low Phosphorus.

5. When the material used at any mill is such that the average phosphorus content of the ingot metal used in the Bessemer process is running below 0.08 and in the Open-Hearth process is running below 0.03, and if it seems mutually desirable, the carbon may be increased at the rate of 0.035 for each 0.01 that the phosphorus content of the ingot metal used averages below 0.08 for Bessemer steel, or 0.03 for Open-Hearth steel.

Average Carbon.

6. It is desired that the percentage of carbon in an entire order of rails shall average as high as the mean percentage between the upper and lower limits specified.

Analyses.

7. In order to ascertain whether the chemical composition is in accordance with the requirements, analyses shall be furnished as follows:

(a) For Bessemer process the manufacturer shall furnish to the inspector, daily, carbon determinations for each heat before the rails are shipped, and two chemical analyses every twenty-four hours representing the average of the elements, carbon, manganese, silicon, phosphorus and sulphur contained in the steel, one for each day and night turn respectively. These analyses shall be made on drillings taken from the ladle test ingot not less than one-eighth inch beneath the surface.

(b) For Open-Hearth process, the makers shall furnish the inspectors with a chemical analysis of the elements, carbon, manganese, silicon, phosphorus and sulphur, for each heat.

(c) On request of the inspector, the manufacturer shall furnish drillings from the test ingot for check analyses.

PHYSICAL REQUIREMENTS.

Physical Qualities.

8. Tests shall be made to determine:

(a) Ductility or toughness as opposed to brittleness.

(b) Soundness.

Method of Testing.

9. The physical qualities shall be determined by the Drop Test.

Drop Testing Machine.

10. The drop testing machine used shall be the standard of the American Railway Engineering Association.

(a) The tup shall weigh 2,000 lbs., and have a striking face with a radius of five inches.

(b) The anvil block shall weigh 20,000 lbs., and be supported on springs.

(c) The supports for the test pieces shall be spaced three feet between centers and shall be a part of, and firmly secured to the anvil. The bearing surfaces of the supports shall have a radius of five inches.

Pieces for Drop Test.

11. Drop tests shall be made on pieces of rail not less than four feet and not more than six feet long. These test pieces shall be cut from the top end of the top rail of the ingot, and marked on the base or head with gage marks one inch apart for three inches each side of the center of the test piece, for measuring the ductility of the metal.

Temperature of Test Pieces.

12. The temperature of the test pieces shall be between 60 and 100 degrees Fahrenheit.

Height of Drop.

13. The test piece shall, at the option of the inspector, be placed head or base upwards on the supports, and be subjected to impact of the tup falling free from the following heights:

For 70-lb. rail ..... 16 feet
For 80, 85 and 90-lb. rail ..... 17 feet
For 100-lb. rail ..... 18 feet

Elongation or Ductility.

14. Under these impacts the rail under one or more blows shall show at least 6 per cent. elongation for one inch, or 5 per cent. each for two consecutive inches of the six-inch scale, marked as described in Section 11.

Permanent Set.

15. It is desired that the permanent set after one blow under the drop test shall not exceed that in the following table, and a record shall be made of this information.

Rail			Permanent Set, measured by Middle Ordinate in Inches in a Length of 3 Feet	
Section	Weight per Yard	Moment of Inertia	Bessemer Process	O.-H. Process
A.R.A.-A	100	48.94	1.65	1.45
A.R.A.-B	100	41.30	2.05	1.80
A.R.A.-A	90	38.70	1.90	1.65
A.R.A.-B	90	32.30	2.20	2.00
A.R.A.-A	80	28.80	2.85	2.45
A.R.A.-B	80	25.00	3.15	2.85
A.R.A.-A	70	21.05	3.50	3.10
A.R.A.-B	70	18.60	3.85	3.50

Test to Destruction.

16. The test pieces which do not break under the first or subsequent blows shall be nicked and broken, to determine whether the interior metal is sound.

Bessemer Process Drop Tests.

17. One piece shall be tested from each heat of Bessemer steel.

(a) If the test piece does not break at the first blow and shows the required elongation (Section 14), all of the rails of the heat shall be accepted, provided that the test piece when nicked and broken does not show interior defect.

(b) If the piece breaks at the first blow, or does not show the required elongation (Section 14), or if the test piece shows the required elongation, but when nicked and broken shows interior defect, all of the top rails from that heat shall be rejected.

(c) A second test shall then be made of a test piece selected by the inspector from the top end of any second rail of the same heat, preferably

of the same ingot. If the test piece does not break at the first blow, and shows the required elongation (Section 14), all of the remainder of the rails of the heat shall be accepted, provided that the test piece when nicked and broken does not show interior defect.

(d) If the piece breaks at the first blow, or does not show the required elongation (Section 14), or if the piece shows the required elongation but when nicked and broken shows interior defect, all of the second rails from that heat shall be rejected.

(e) A third test shall then be made of a test piece selected by the inspector from the top end of any third rail of the same heat, preferably of the same ingot. If the test piece does not break at the first blow and shows the required elongation (Section 14), all of the remainder of the rails of the heat shall be accepted, provided that the test piece when nicked and broken does not show interior defect.

(f) If the piece breaks at the first blow, or does not show the required elongation (Section 14), or if the piece shows the required elongation but when nicked and broken shows interior defect, all of the remainder of the rails from that heat shall be rejected.

Open-Hearth Process Drop Tests.

18. Test pieces shall be selected from the second, middle and last full ingot of each Open-Hearth heat.

(a) If two of these test pieces do not break at the first blow and show the required elongation (Section 14), all of the rails of the heat shall be accepted, provided that these test pieces when nicked and broken do not show interior defect.

(b) If two of the test pieces break at the first blow, or do not show the required elongation, or if any of the pieces that have been tested under the drop when nicked and broken show interior defect, all of the top rails from that heat shall be rejected.

(c) Second tests shall then be made from three test pieces selected by the inspector from the top end of any second rails of the same heat, preferably of the same ingots. If two of these test pieces do not break at the first blow and show the required elongation (Section 14), all of the remainder of the rails of the heat shall be accepted, provided that the pieces that have been tested under the drop when nicked and broken do not show interior defect.

(d) If two of these test pieces break at the first blow or do not show the required elongation (Section 14), or if any of the pieces that have been tested under the drop when nicked and broken show interior defect, all of the second rails of the heat shall be rejected.

(e) Third tests shall then be made from three test pieces selected by the inspector from the top end of any third rails of the same heat, preferably of the same ingots. If two of these test pieces do not break at the first blow, and show the required elongation (Section 14), all of the remainder of the rails of the heat shall be accepted, provided that the

pieces that have been tested under the drop when nicked and broken do not show interior defect.

(f) If two of these test pieces break at the first blow or do not show the required elongation (Section 14), or if any of the pieces, that have been tested under the drop when nicked and broken show interior defect, all of the remainder of the rails from that heat shall be rejected.

No. 1 Rails.

19. No. 1 classification rails shall be free from injurious defects and flaws of all kinds.

No. 2 Rails.

20. (a) Rails, which, by reason of surface imperfections, or for causes mentioned in Section 30 hereof, are not classed as No. 1 rails, will be accepted as No. 2 rails, but No. 2 rails which contain imperfections in such number or of such character as will, in the judgment of the inspector, render them unfit for recognized No. 2 uses, will not be accepted for shipment.

(b) No. 2 rails to the extent of 5 per cent. of the whole order will be received. All rails accepted as No. 2 rails shall have the ends painted white and shall have two prick punch marks on the side of the web near the heat number near the end of the rail, so placed as not to be covered by the splice bars.

DETAILS OF MANUFACTURE.

Quality of Manufacture.

21. The entire process of manufacture shall be in accordance with the best current state of the art.

Bled Ingots.

22. Bled ingots shall not be used.

Discard.

23. There shall be sheared from the end of the bloom, formed from the top of the ingot, sufficient metal to secure sound rails.

Lengths.

24. The standard length of rails shall be 33 feet, at a temperature of 60 degrees Fahrenheit. Ten per cent. of the entire order will be accepted in shorter lengths varying by 1 foot from 32 feet to 25 feet. A variation of one-fourth inch from the specified lengths will be allowed. No. 1 rails less than 33 feet long shall be painted green on both ends.

Shrinkage.

25. The number of passes and speed of train shall be so regulated that on leaving the rolls at the final pass, the temperature of the rail will not exceed that which requires a shrinkage allowance at the hot saws, for a rail 33 feet in length and of 100 lbs. section, of six and three-fourths inches and one-eighth inch less for each ten lbs. decrease in section.

Cooling.

26. The bars shall not be held for the purpose of reducing their temperature, nor shall any artificial means of cooling them be used after they leave the finishing pass. Rails, while on the cooling beds, shall be protected from snow and water.

Section.

27. The section of rails shall conform as accurately as possible to the template furnished by the Railroad Company. A variation in height of one-sixty-fourth inch less or one-thirty-second inch greater than the specified height, and one-sixteenth inch in width of flange, will be permitted; but no variation shall be allowed in the dimensions affecting the fit of the splice bars.

Weight.

28. The weight of the rails specified in the order shall be maintained as nearly as possible, after complying with the preceding Section. A variation of one-half of 1 per cent. from the calculated weight of section, as applied to an entire order, will be allowed.

Payment.

*29. Rails will be accepted and paid for according to actual weights.

Straightening.

30. The hot straightening shall be carefully done, so that gagging under the cold presses will be reduced to a minimum. Any rail coming to the straightening presses showing sharp kinks or greater camber than that indicated by a middle ordinate of 4 inches in 33 feet, for A. R. A. type of sections, or 5 inches for A. S. C. E. type of sections, will be at once classed as a No. 2 rail. The distance between the supports of rails in the straightening presses shall not be less than 42 inches. The supports shall have flat surfaces and be out of wind.

Drilling.

31. Circular holes for joint bolts shall be drilled to conform accurately in every respect to the drawing and dimensions furnished by the Railroad Company.

Finishing.

32. (a) All rails shall be smooth on the heads, straight in line and surface, and without any twists, waves or kinks. They shall be sawed square at the ends, a variation of not more than one-thirty-second inch being allowed; and burrs shall be carefully removed.

(b) Rails improperly drilled or straightened, or from which the burrs have not been removed, shall be rejected, but may be accepted after being properly finished.

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*Amend to read, "29. Rails accepted will be paid for according to actual weights."

Branding.

33. The name of the manufacturer, the weight and type of rail, and the month and year of manufacture shall be rolled in raised letters and figures on the side of the web. The number of the heat and a letter indicating the portion of the ingot from which the rail was made shall be plainly stamped on the web of each rail, where it will not be covered by the splice bars. The top rails shall be lettered "A," and the succeeding ones "B," "C," "D," etc., consecutively; but in case of a top discard of twenty or more per cent., the letter "A" will be omitted. Open-Hearth rails shall be branded or stamped "O. H." All markings of rails shall be done so effectively that the marks may be read as long as the rails are in service.

Separate Classes.

34. All classes of rails shall be kept separate from each other.

Loading.

35. All rails shall be loaded in the presence of the inspector.

Appendices to Report of Committee IV—On Rail.

Your Committee submits the following statements as Appendices to its report. They consist of:

(A) A Study of Seventeen Good Service Rails, by Robert Trimble and W. C. Cushing (Bulletin 135, May, 1911), with notes by M. H. Wickhorst.

(B) Rail Failure Statistics for the Year Ending October 31, 1910; Comparative Wear of Bessemer, Open-Hearth and Nickel Steel Rail on Pennsylvania Railroad, by Jos. T. Richards, Chief Engineer Maintenance of Way.

(C) Segregation and Other Rail Properties as Influenced by the Size of Ingot, by M. H. Wickhorst (Bulletin 137, July, 1911).

(D) Tests of Rail Steel Ingots and Derivative Shapes Made at Watertown Arsenal, being a Review, by M. H. Wickhorst, of the Report published by the Watertown Arsenal (Bulletin 139, September, 1911).

(E) Influence ef Rolling Temperature on the Properties of Bessemer Rails, by M. H. Wickhorst (Bulletin 143, January, 1912).

(F) Hearing before Railroad Commission of Indiana (Bulletin 144, February, 1912).

Appendix A.

A STUDY OF SEVENTEEN GOOD SERVICE RAILS

By

Robert Trimble and W. C. Cushing.

With discussion by

M. H. Wickhorst, Engineer of Tests—Rail Committee.

This report covers a study of seventeen Bessemer rails that gave good service on the Pennsylvania Lines West of Pittsburgh, ten of them on the Northwest System, the reports of which were furnished by Mr. Trimble, Chief Engineer Maintenance of Way, and the other seven on the Southwest System, the reports of which were furnished by Mr. Cushing, Chief Engineer Maintenance of Way. The rails gave from seven to seventeen years' service in main tracks and were removed under directions of Messrs. Trimble and Cushing for special examination. The tests (which were made by R. W. Hunt & Co.) consisted of the following:

1. Etching of a section with picric acid.
2. Etching of a section with sulphuric acid.
3. Analysis of borings from the interior of the head.
4. Tensile strength of a sample from the interior of the head, from eleven of the rails.
5. Five transverse microphotographs along the center line of the rail, one at the top and the others at ¼ in., ½ in., ¾ in. and 1 in., respectively from the top, from each rail, etched with picric acid and magnified about 65 diameters.

These various reports and other information were presented to the Rail Committee and then edited for publication as this report by M. H. Wickhorst. The rails were given numbers from 1 to 17, inclusive, the first ten being rails examined by Trimble, and the other seven examined by Cushing. The main information concerning these rails is shown in Table 1, and for more convenient comparison the carbon, phosphorus, manganese, tensile strength and elongation are shown graphically in Fig. 1. The present specification limits for carbon, phosphorus and manganese are shown on the diagrams, namely, carbon, .45 to .55 per cent; phosphorus, not exceeding .10 per cent., and manganese, .80 to 1.10 per cent. Although we have no standard tensile requirements, I show a line at 12 per cent. elongation, as Bessemer rail steel should give this amount below the

Report No. 18, April, 1911.

TABLE 1—85-LB. RAILS.

Rail No.	Section	Years Service	Maker	Probable Ingot Position	Curve or Tangent	High or Low Rail	Tens. Str. per Sq. In.	Elong. % in 2"	Reduct. of Area	C	P	S	Mn.	Si.
1	P. R. R.	16	Carnegie	A	2°	H	.....	.....	.....	.475	.127	.043	.85	.040
2	P. R. R.	16	Carnegie	B	2°	L	.....	.....	.....	.556	.135	.050	1.05	.090
3	P. R. R.	17	Carnegie	B	T	.....	.....	.....	.....	.497	.118	.031	1.01	.076
4	P. R. R.	17	Carnegie	A	T	.....	.....	.....	.....	.560	.156	.044	1.04	.075
5	P. R. R.	17	Carnegie	A	2°08′	L & H	.....	.....	.....	.641	.189	.053	.70	.051
6	P. R. R.	17	Carnegie	A	2°08′	L & H	.....	.....	.....	.591	.146	.044	.69	.049
7	P. R. R.	14	Illinois	L	0°40′	L	112,120	20.5	37.39	.452	.098	.....	.87	.168
8	P. R. R.	14	Illinois	L	2°20′	L	121,240	18	37.59	.489	.101	.....	.96	.142
9	P. R. R.	14	Illinois	L	0°40′	H	116,450	18.5	31.74	.480	.102	.....	.91	.163
10	P. R. R.	14	Illinois	L	2°20′	H	117,580	19	30.11	.478	.097	.....	1.01	.149
11	A. S. C. E.	11	Carnegie	L	T	.....	121,650	16	22.21	.579	.094	.....	1.04	.149
12	P. R. R.	15½	Illinois	A	T	.....	113,450	6.5	4.75	.476	.091	.....	1.06	.133
13	P. R. R.	17½	Carnegie	B	T	.....	116,510	18	26.39	.493	.126	.....	1.06	.149
14	A. S. C. E.	11	Carnegie	A	T	.....	117,540	4	5.57	.591	.119	.....	.78	.079
15	A. S. C. E.	11	Carnegie	L	T	.....	118,440	15	19.00	.558	.101	.....	.96	.118
16	A. S. C. E.	7	Carnegie	L	T	.....	117,580	18.5	28.43	.515	.113	.....	1.08	.135
17	A. S. C. E.	7½	Carnegie	L	T	.....	102,900	23.5	38.82	.476	.096	.....	.79	.056

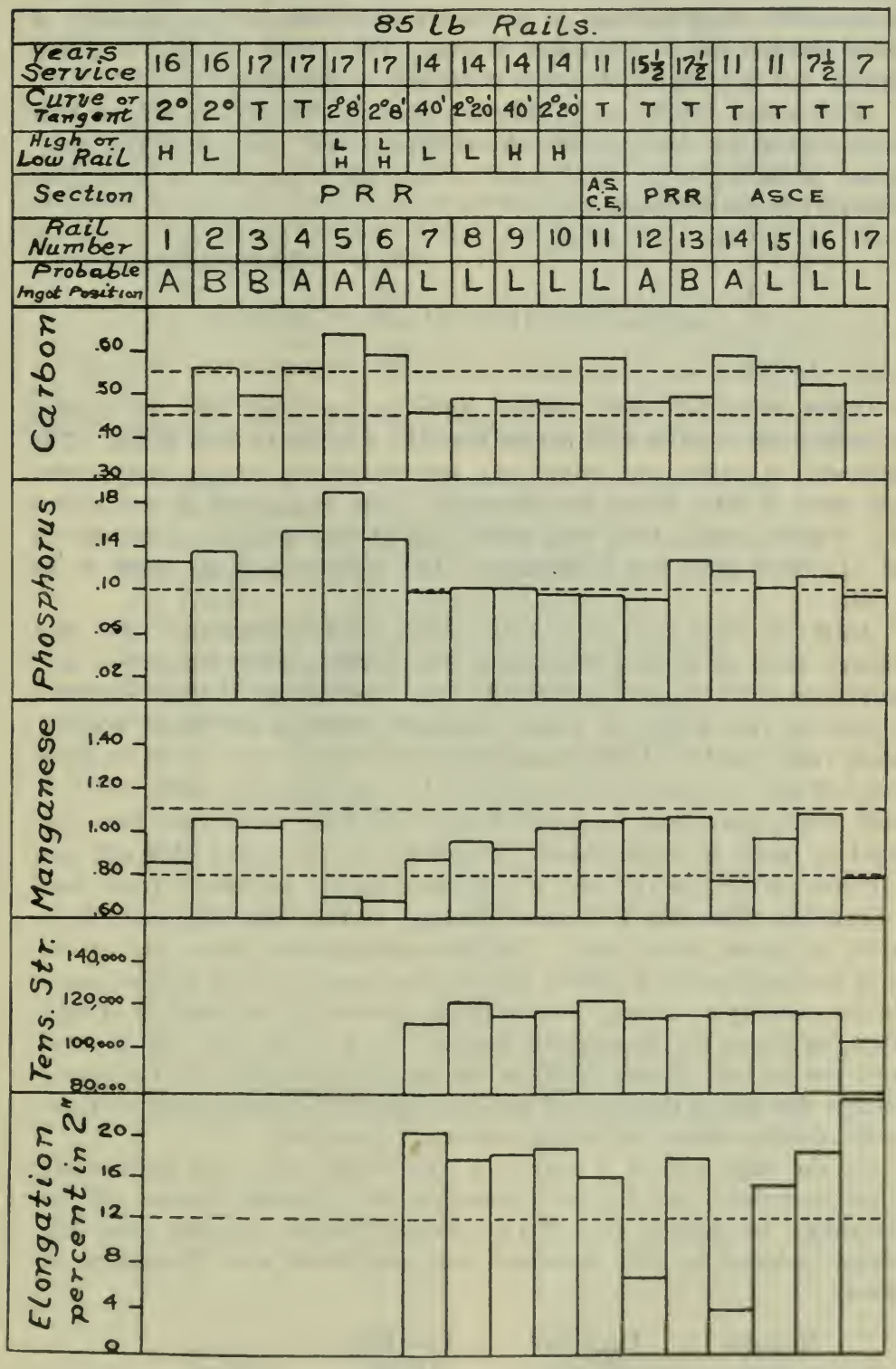

85 lb Rails.
Years Service
16 16 17 17 17 17 14 14 14 14 11 15½ 17½ 11 11 7½ 7
Curve or Tangent
2° 2° T T 2°8' 2°8' 40' 2°20' 40' 2°20' T T T T T T T
High or Low Rail
H L L H L H L L H H
Section
P R R
A.S. C.E.
PRR
ASCE
Rail Number
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Probable Ingot Position
A B B A A A L L L L L A B A L L L
Carbon
.60
.50
.40
.30
Phosphorus
.18
.14
.10
.06
.02
Manganese
1.40
1.20
1.00
.80
.60
Tens. Str.
140,000
120,000
100,000
80,000
Elongation percent in 2"
20
16
12
8
4
0

FIG. 1.

brittle zone near the top of the ingot. In both Table 1 and Fig. 1, I show the probable ingot position of the rail as indicated by the etchings; A means the top rail of the ingot, B means the second rail, and L means that the rail is probably from the lower part of the ingot.

The carbon results are within the prescribed limits, or only a little above, except in rail 5, which shows carbon .641 per cent. The phosphorus is above .10 per cent. in over half the cases, and in several of them very much so, namely:

Rail 5	.189	per cent	phosphorus
" 4	.156	"	"	"
" 6	.146	"	"	"
" 2	.135	"	"	"

These rails also show carbon above .55 per cent., and the etching indicates them to be A rails except that rail 2 seems to be a B rail. The manganese is pretty well within the specified limits, except that several rails show a little below the minimum. The elongation in the eleven rails of which tensile tests were made showed very well except in rails 12 and 14, which gave low elongations. The etchings indicate these to be A rails.

Most of these rails would be called good commercial rails, and although some of them come outside the specified limits for carbon and phosphorus, there is not a sufficiently high combination of these elements to result in very brittle or fragile material, except in rail 5 and possibly also in rails 4 and 6. Unfortunately, no tensile tests were made on these rails, but rail 5, at the location where the analysis was made, must, it would seem, have been very brittle material, and would have been expected to result in a split head. According to the record, this rail was in service on the low rail of a 2° 08′ curve on the westbound track west of Crestline, Ohio, for ten years, changed to the high side and left in service for seven years more. The microphotographs show that at the top of the head and ¼ in. below the top the metal is of low carbon, probably not over .35 or .40 per cent., although below this the metal is of high carbon, as shown by the analysis, namely, .641 per cent., but still the rail seems not to have flowed badly while on the inner side of the curve. Whether this means that the rail was not subjected to very severe, or there was some other reason for its long service, I cannot say.

On the high rail of a curve the rail seems not to be particularly subject to failure, and in this connection the following figures will be interesting. In Reports 12 and 13, covering studies of failed rails, Mr. Cushing included 52 split Bessemer rails, and these were distributed as follows:

Straight Line.	High Rail of Curve.	Low Rail of Curve.	Total.
25 rails	4 rails	23 rails	52 rails
48 per cent.	8 per cent.	44 per cent.	100 per cent.

As to what the relative probability is of failure on straight line and on curve, the above figures do not show, as we cannot say the number of miles of track represented by the above failures, but they would seem to indicate that the liability to failure is about 15 per cent on the high of what it is on the low rail.

Conclusion.—This study indicates that the present specifications for Bessemer rails are consistent with long service and that under some conditions a segregated rail high in phosphorus, and possibly also carbon. may give long service, although it does not define these conditions, either of track or of material.

REPORTS OF INDIVIDUAL RAILS.

The rest of this report deals with statements concerning the individual rails, photographs of sections etched with picric acid and five microphotographs of each rail. The following abbreviations are used:

C = carbon.
P = phosphorus.
S = sulphur.
Mn = manganese.
Si = silicon.
E. L. = elastic limit.
T. S. = tensile strength.
Elong. = elongation.
Red. area = reduction of area

RAIL 1.

Carnegie 85-lb. P. R. R. section bessemer steel, rolled April, 1893, heat 890. High rail of 2-degree curve, east of Highland, Pa., grade .87 per cent. In service 16 years. Rail was originally in eastbound track. In 1904 this became eastbound freight track. Some of this rail still in track in good condition. Speed on main track, 60 miles per hour. Speed on freight track, 40 miles per hour.

C .475, Mn .85, P .127, Si .040, S .043.

Fig. 2. Rail 1, Etched with Picric Acid.

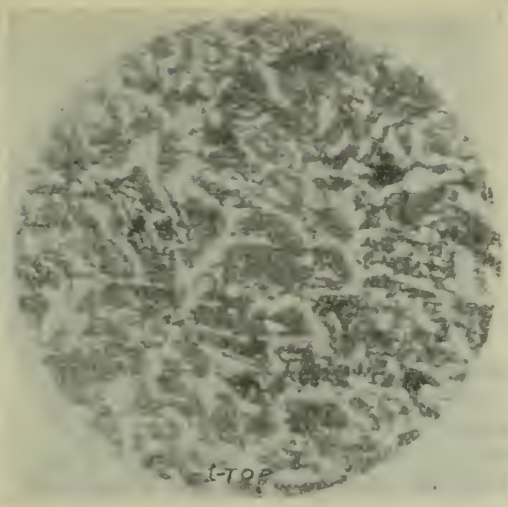


FIG. 3. RAIL 1, AT TOP OF HEAD.

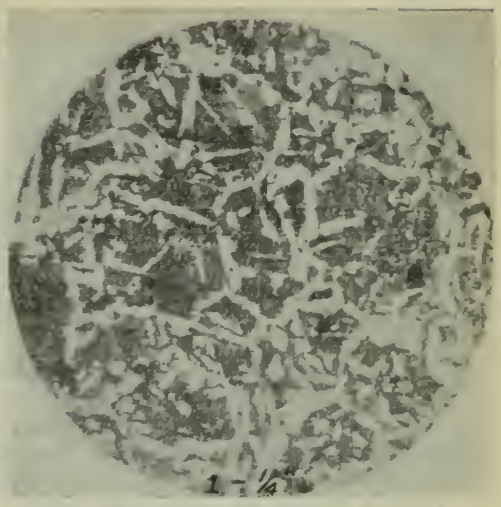


FIG. 4. RAIL 1, ¼ IN. BELOW TOP

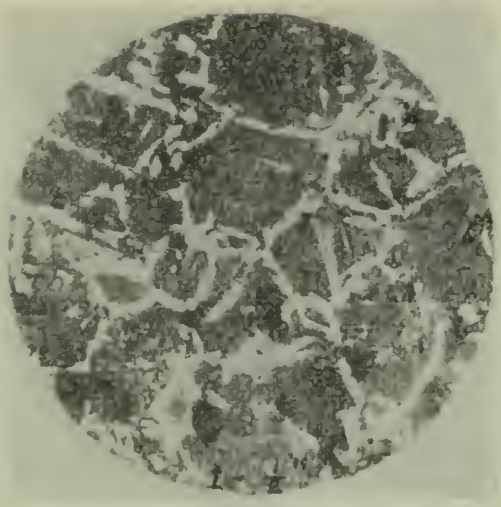


FIG. 5. RAIL 1, ½ IN. BELOW TOP.

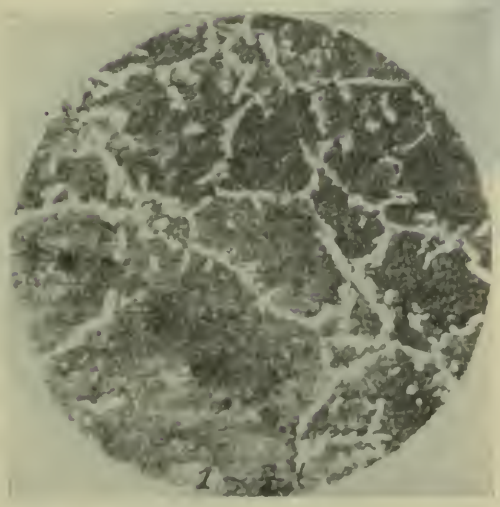


FIG. 6. RAIL 1, ¾ IN. BELOW TOP.

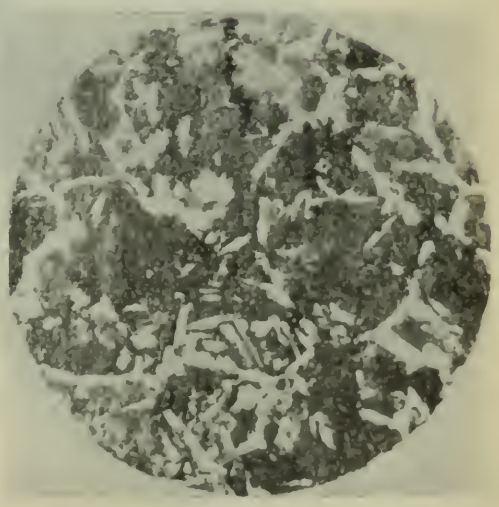


FIG. 7. RAIL 1, 1 IN. BELOW TOP.

MICROPHOTOGRAPHS OF RAIL 1, MAGNIFIED ABOUT 65 DIAMETERS

RAIL 2.

Carnegie 85-lb. P. R. R. section bessemer steel, rolled December, 1892, heat 4803. Low rail of 2-degree curve, east of Highland, Pa., grade .87 per cent. In service 16 years. Rail originally in eastbound main track. In 1904 this became eastbound freight track. Some of this rail still in track in good condition. Speed on main track, 60 miles per hour. Speed on freight track, 40 miles per hour.

C .556, Mn 1.05, P .135, Si .090, S .050.

FIG. 8. RAIL 2, ETCHED WITH PICRIC ACID.

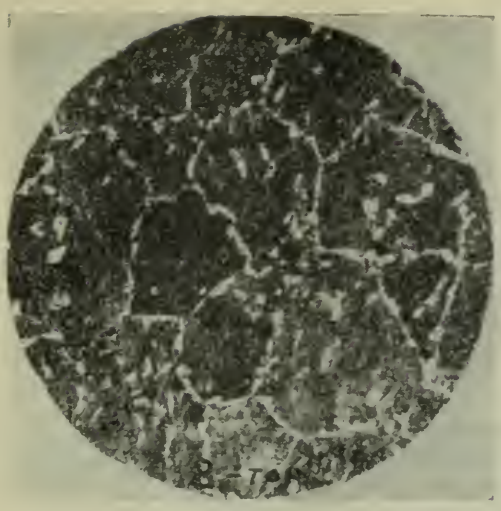


FIG. 9. RAIL 2, AT TOP OF HEAD.

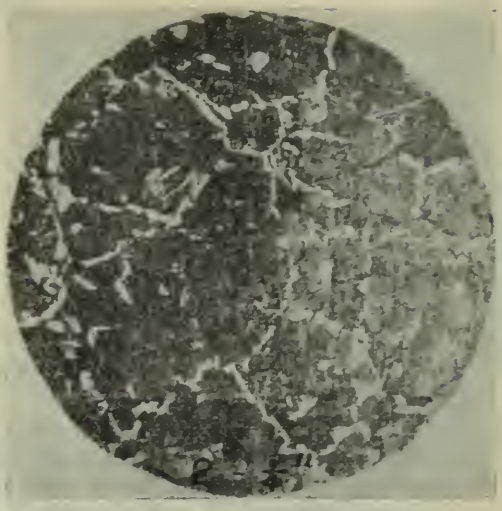


FIG. 10. RAIL 2, ¼ IN. BELOW TOP.

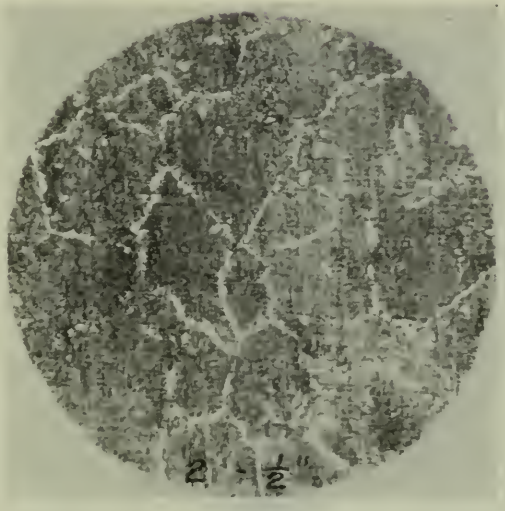


FIG. 11. RAIL 2, ½ IN. BELOW TOP.

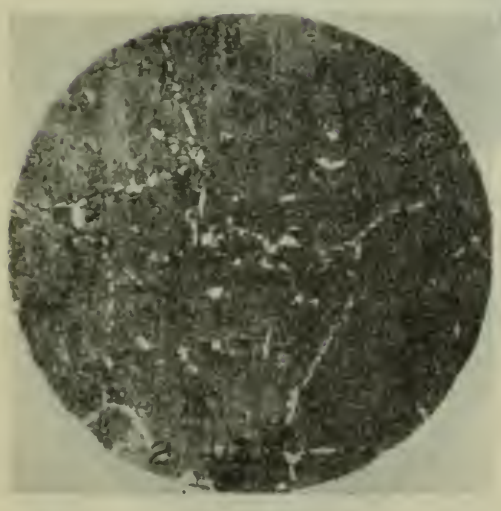


FIG. 12. RAIL 2, ¾ IN. BELOW TOP.

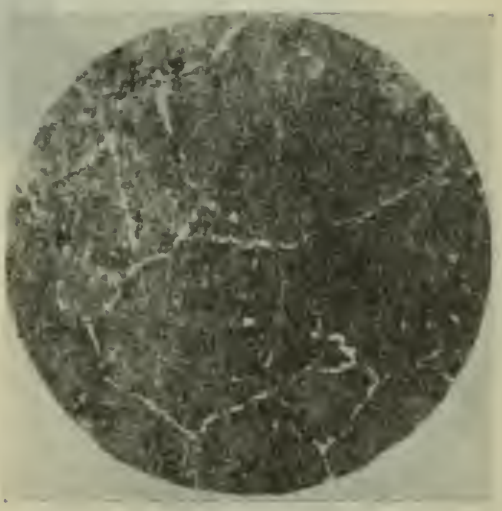


FIG. 13. RAIL 2, 1 IN. FROM TOP.

MICROPHOTOGRAPHS OF RAIL 2, MAGNIFIED ABOUT 65 DIAMETERS.

RAIL 3.

Carnegie 85-lb. P. R. R. section bessemer steel, rolled August, 1892. heat 2753. On tangent, eastbound track, East Division, west of Crestline. O. In service 17 years. Some still in track in good condition.
C .497, Mn 1.01, P .118, Si .076, S .031.

FIG. 14. RAIL 3, ETCHED WITH PICRIC ACID.

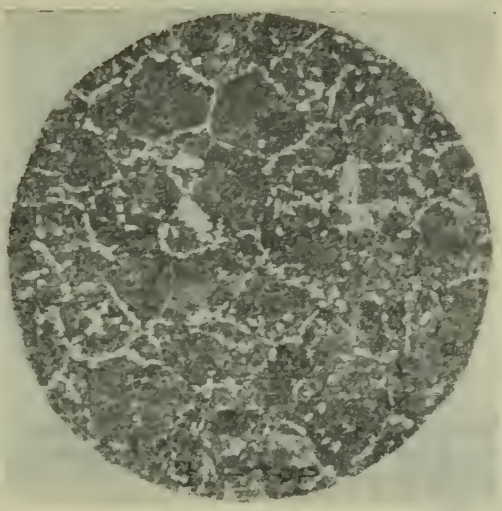


FIG. 15. RAIL 3, AT TOP OF HEAD.

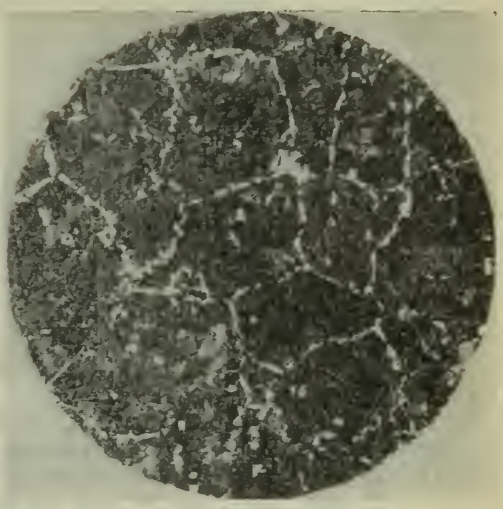


FIG. 16. RAIL 3, ¼ IN. BELOW TOP.

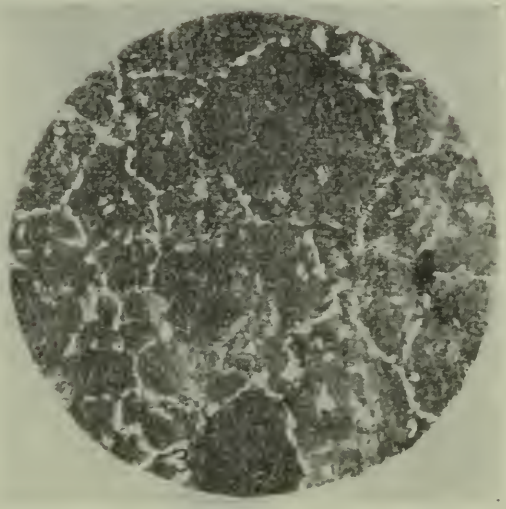


FIG. 17. RAIL 3, ½ IN. BELOW TOP.

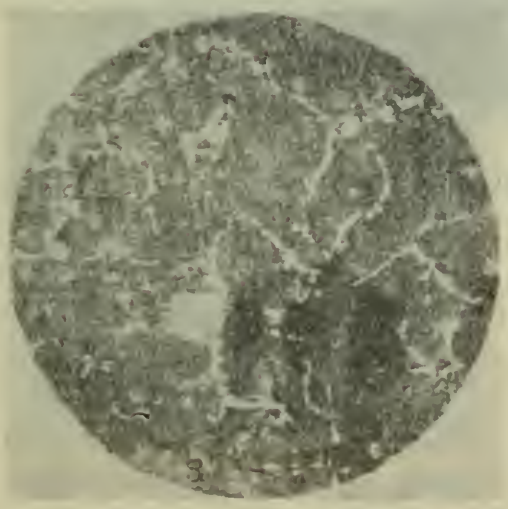


FIG. 18. RAIL 3, ¾ IN. BELOW TOP.

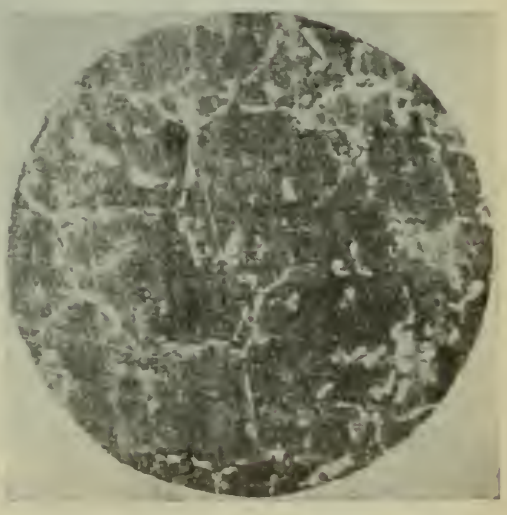


FIG. 19. RAIL 3, 1 IN. BELOW TOP.

MICROPHOTOGRAPHS OF RAIL 3, MAGNIFIED ABOUT 65 DIAMETERS.

RAIL 4.

Carnegie 85-lb. P. R. R. section bessemer steel, rolled August, 1892, heat 2764. On tangent, eastbound track, East Division, west of Crestline.
O In service 17 years. Some still in track in good condition.
C .560, Mn 1.04, P .156, Si .075, S .044.

Fig. 20. Rail 4, Etched with Picric Acid.

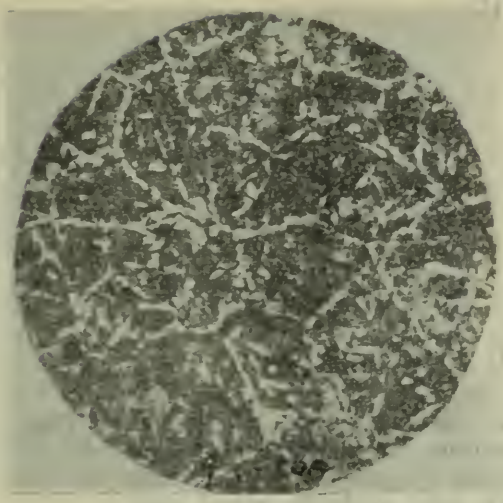


FIG. 21. RAIL 4, AT TOP OF HEAD.

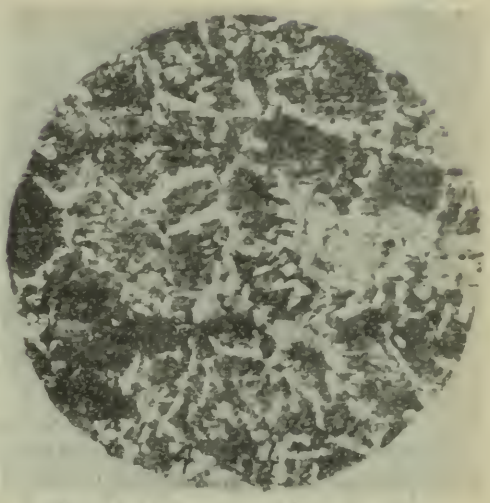


FIG. 22. RAIL 4, ¼ IN. BELOW TOP.

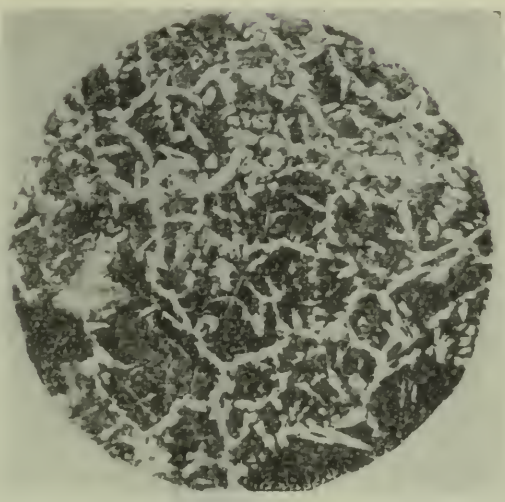


FIG. 23. RAIL 4, ½ IN. BELOW TOP.

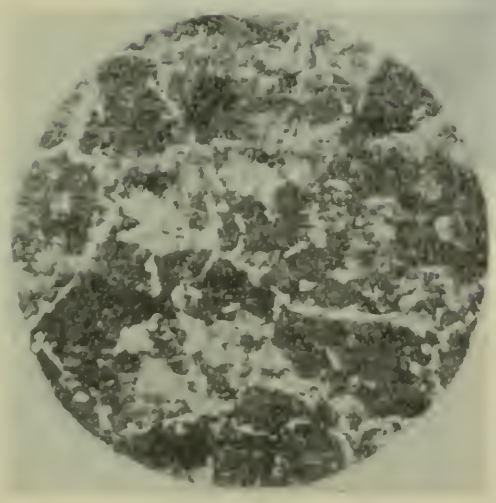


FIG. 24. RAIL 4, ¾ IN. BELOW TOP.

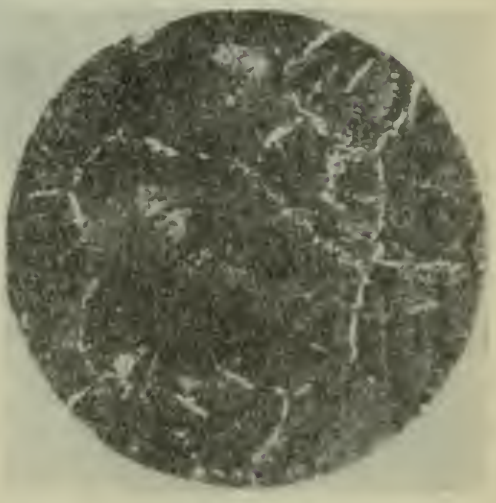


FIG. 25. RAIL 4, 1 IN. BELOW TOP.

MICROPHOTOGRAPHS OF RAIL 4, MAGNIFIED ABOUT 65 DIAMETERS.

RAIL 5.

Carnegie 85-lb. P. R. R. section bessemer steel, rolled April, 1892, heat 1872. High rail 2 degrees, 08 minute curve, East Division, west of Crestline, O., westbound track. In service 17 years. Rail originally on low side of curve, but was changed to high side, probably about 1903.

C .641, Mn .70, P .189, Si .051, S .053.

FIG. 26. RAIL 5, ETCHED WITH PICRIC ACID.

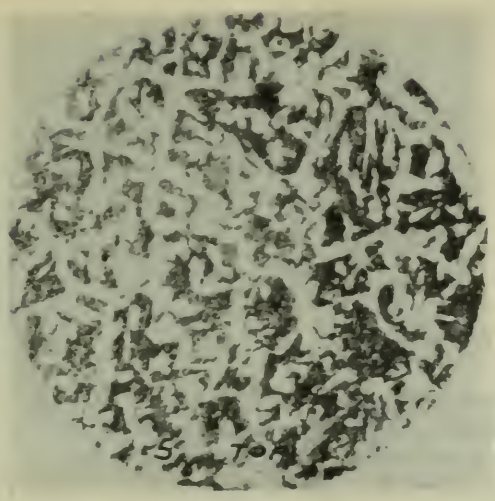


FIG. 27. RAIL 5, AT TOP OF HEAD.

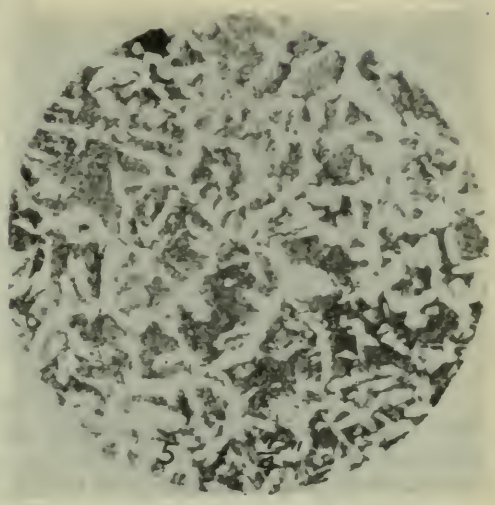


FIG. 28. RAIL 5, ¼ IN. BELOW TOP.

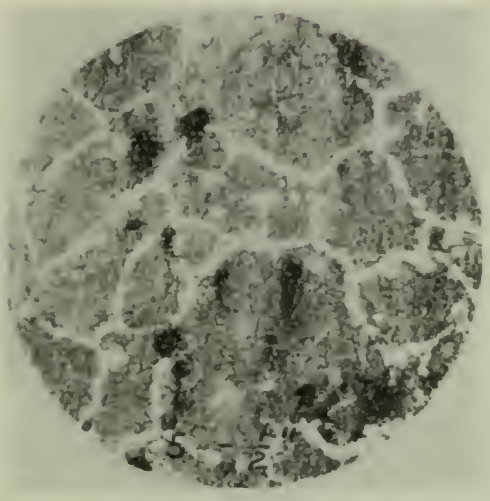


FIG. 29. RAIL 5, ½ IN. BELOW TOP.

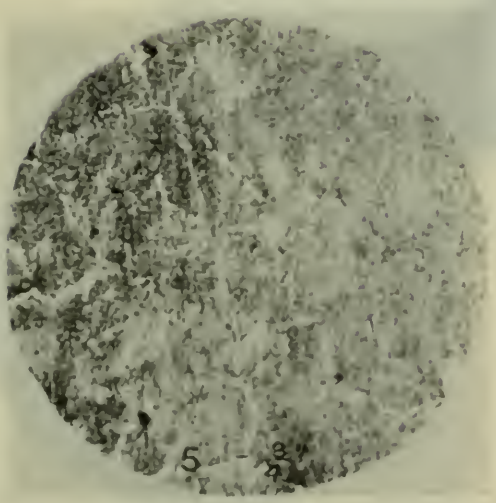


FIG. 30. RAIL 5, ¾ IN. BELOW TOP.

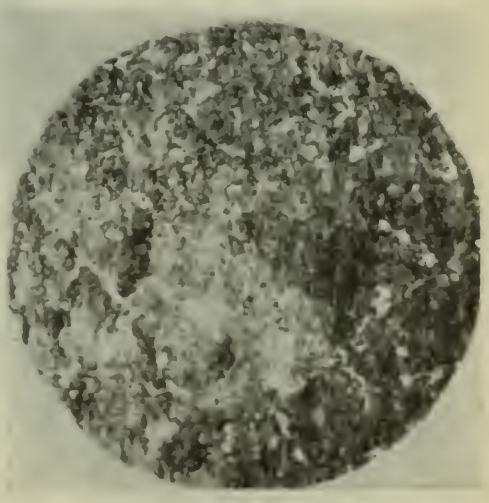


FIG. 31. RAIL 5, 1 IN. BELOW TOP.

MICROPHOTOGRAPHS OF RAIL 5, MAGNIFIED ABOUT 65 DIAMETERS.

RAIL 6.

Carnegie 85-lb. P. R. R. section bessemer steel, rolled April, 1892, heat 1894. High rail of 2 degrees, 08 minute curve, westbound track, East Division, west of Crestline, O. In service 17 years. Rail was originally on low side, but was changed to high side, probably about 1903.

C .591, Mn .69, P .146, Si .049, S .044.

FIG. 32. RAIL 6, ETCHED WITH PICRIC ACID.

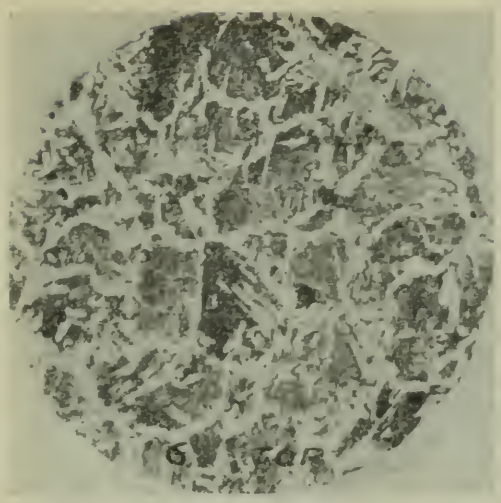


FIG. 33. RAIL 6, AT TOP OF HEAD.

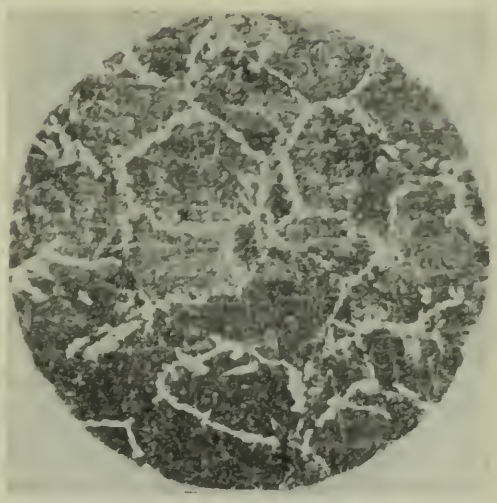


FIG. 34. RAIL 6, ¼ IN. BELOW TOP.

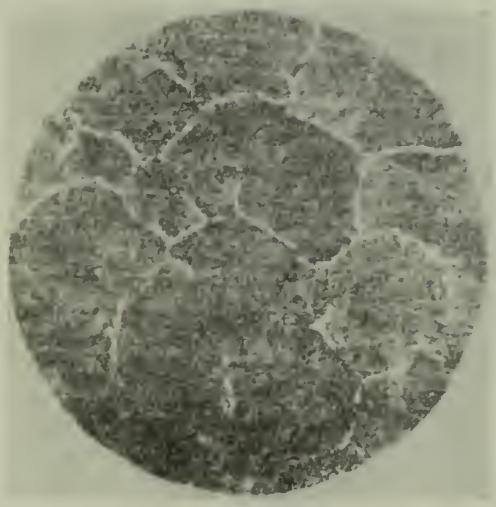


FIG. 35. RAIL 6, ½ IN. BELOW TOP.

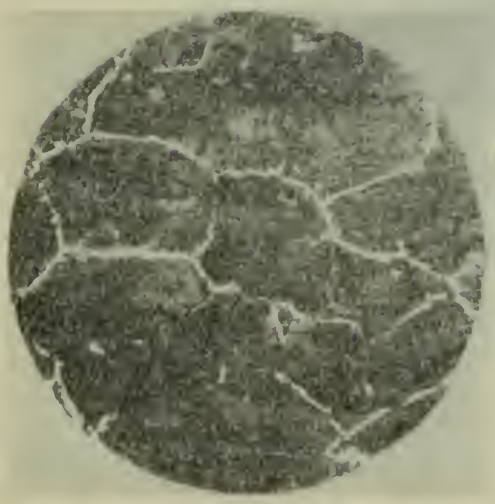


FIG. 36. RAIL 6, ¾ IN. BELOW TOP.

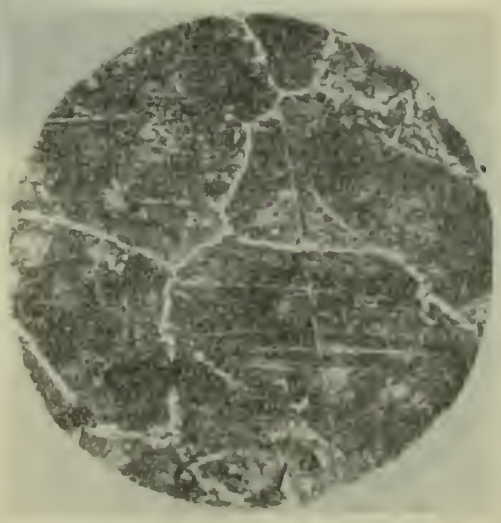


FIG. 37. RAIL 6, 1 IN. BELOW TOP.

MICROPHOTOGRAPHS OF RAIL 6, MAGNIFIED ABOUT 65 DIAMETERS.

RAIL 7.

Illinois 85-lb. P. R. R. section bessemer steel, rolled November, 1895, heat 39420. Low rail of 0 degree, 40 minute curve, westbound track, West Division, east of Valparaiso, Ind. In service 14 years.

C .452, Mn .87, P .098, Si .168, T. S. 112,120 lbs. per sq. in., E. L. 71,470 lbs. per sq. in., elong. 20.5 per cent. in 2 in., red. area 37.39 per cent.

FIG. 38. RAIL 7, ETCHED WITH PICRIC ACID.

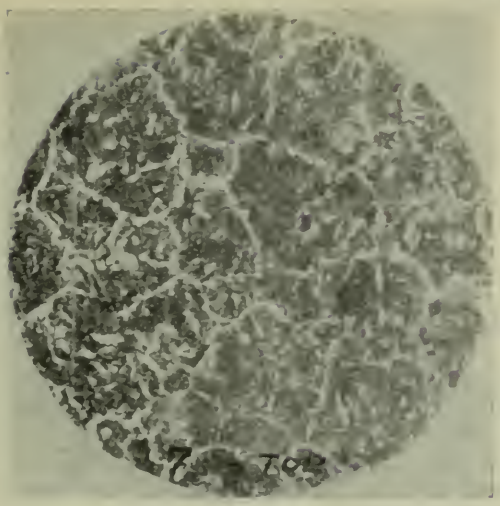


FIG. 39. RAIL 7, AT TOP OF HEAD.

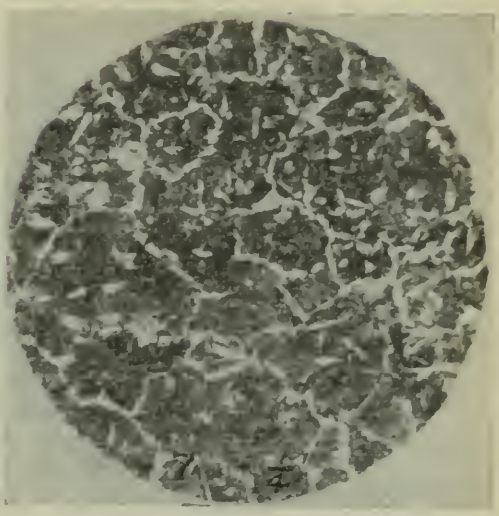


FIG. 40. RAIL 7, ¼ IN. BELOW TOP.

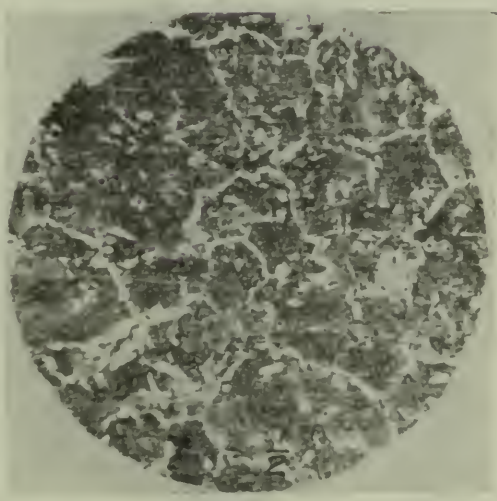


FIG. 41. RAIL 7, ½ IN. BELOW TOP.

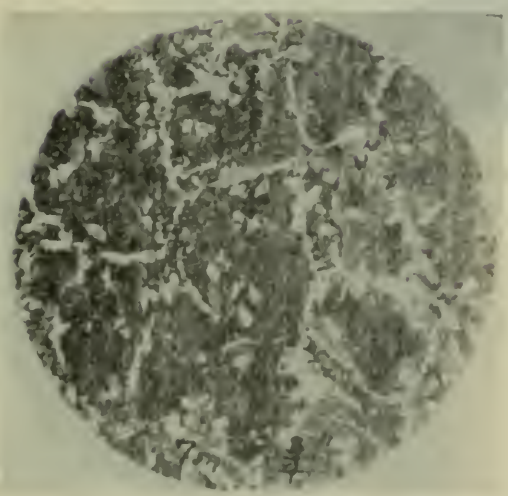


FIG. 42. RAIL 7, ¾ IN. BELOW TOP.

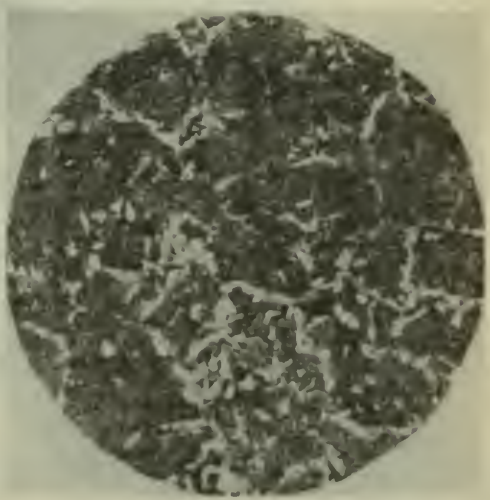


FIG. 43. RAIL 7, 1 IN. BELOW TOP.

MICROPHOTOGRAPHS OF RAIL 7, MAGNIFIED ABOUT 65 DIAMETERS.

RAIL 8.

Illinois 85-lb. P. R. R. section bessemer steel, rolled November, 1895, heat 39503. Low rail of 2 degrees, 20 minute curve, West Division, east of Valparaiso, Ind. In service 14 years, laid 1896.

C .489, Mn .96, P .101, Si .142, T. S. 121,240 lbs. per sq. in., E. L. 70,900 lbs. per sq. in., elong. 18 per cent. in 2 in., red. area 37.59 per cent.

FIG. 44. RAIL 8, ETCHED WITH PICRIC ACID.

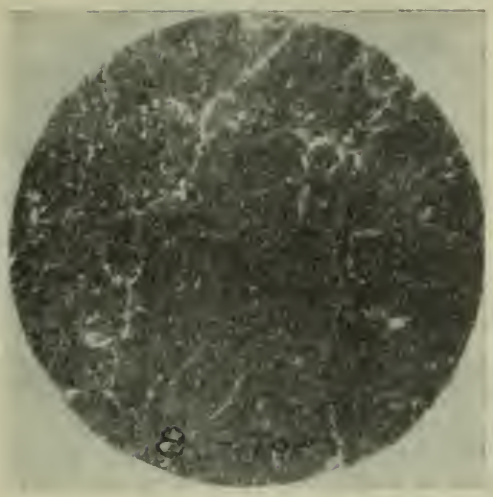


FIG. 45. RAIL 8, AT TOP OF HEAD.

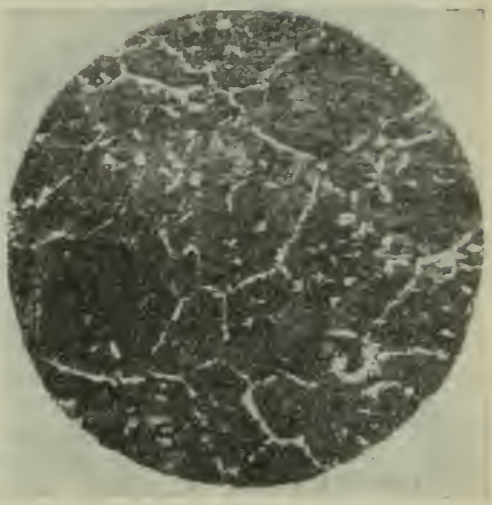


FIG. 46. RAIL 8, ¼ IN. BELOW TOP.

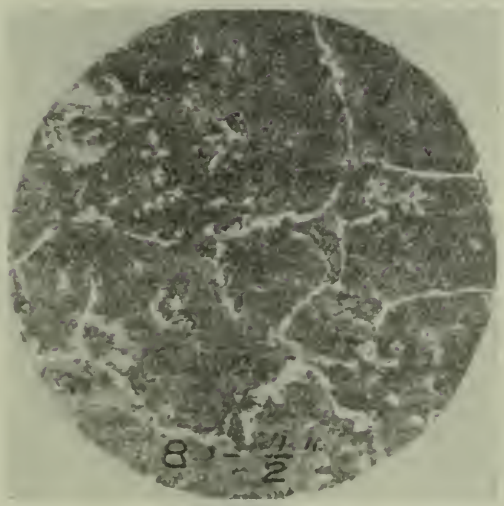


FIG. 47. RAIL 8, ½ IN. BELOW TOP.

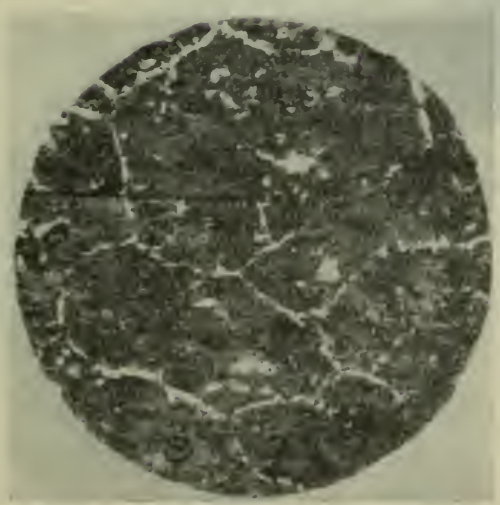


FIG. 48. RAIL 8, ¾ IN. BELOW TOP.

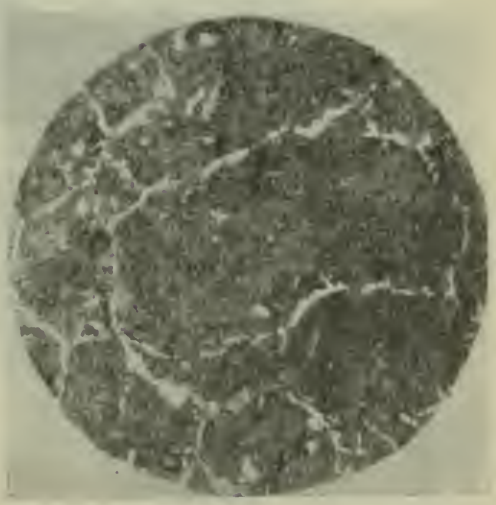


FIG. 49. RAIL 8, 1 IN. BELOW TOP.

MICROPHOTOGRAPHS OF RAIL 8, MAGNIFIED ABOUT 65 DIAMETERS.

RAIL 9.

Illinois 85-lb. P. R. R. section bessemer steel, rolled November, 1895, heat 39420. High rail of 0 degree, 40 minute curve, westbound track, West Division, east of Valparaiso, Ind. In service 14 years, laid 1896.

C .480, Mn .91, P .102, Si .163, T. S. 116,450 lbs. per sq. in., E. L. 74,940 lbs. per sq. in., elong. 18.5 per cent. in 2 in., red. area 31.74 per cent.

Fig. 50. Rail 9, Etched with Picric Acid.

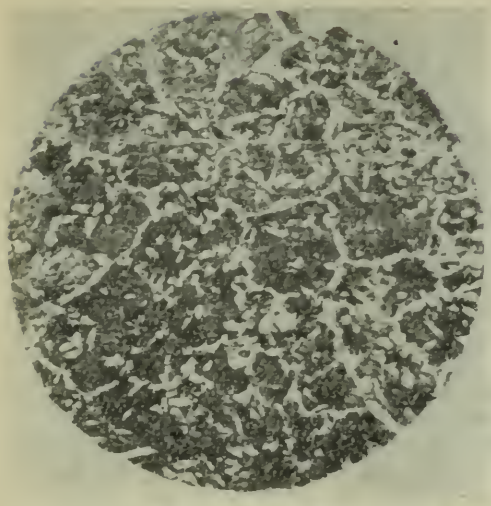


FIG. 51. RAIL 9, AT TOP OF HEAD.

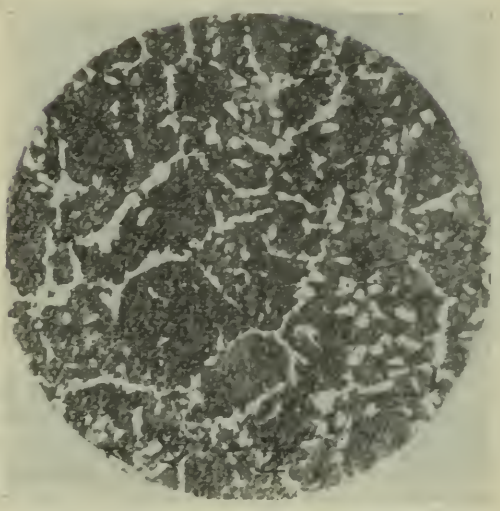


FIG. 52. RAIL 9, ¼ IN. BELOW TOP.

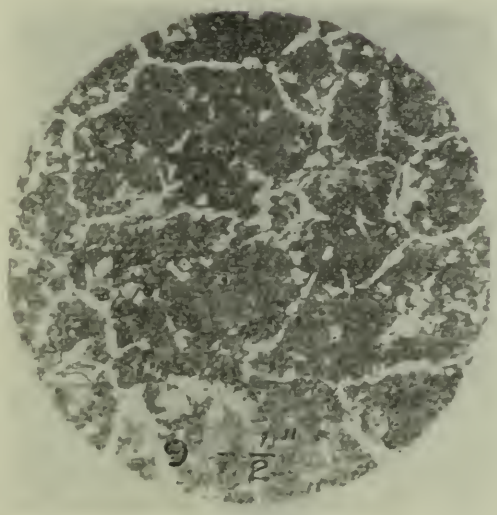


FIG. 53. RAIL 9, ½ IN. BELOW TOP.

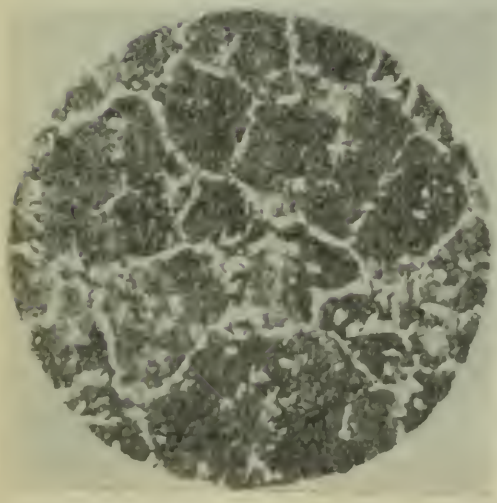


FIG 54. RAIL 9, ¾ IN. BELOW TOP.

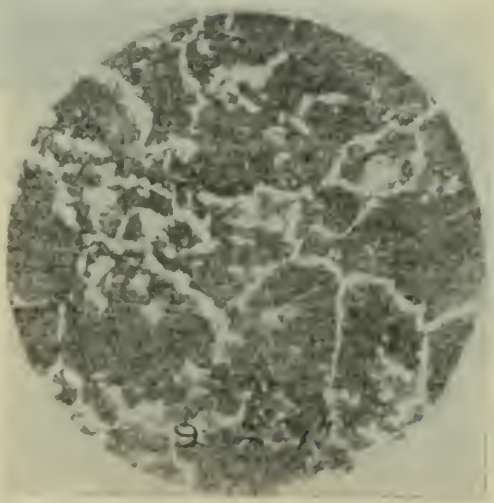


FIG. 55. RAIL 9, 1 IN. BELOW TOP.

MICROPHOTOGRAPHS OF RAIL 9, MAGNIFIED ABOUT 65 DIAMETERS.

RAIL 10.

Illinois 85-lb. P. R. R. section bessemer steel, rolled November, 1895, heat 39513. High rail of 2 degrees, 20 minute curve, westbound track, West Division, east of Valparaiso, Ind. In service 14 years, laid 1895.

C .478, Mn 1.01, P .097, Si .149, T. S. 117,580 lbs. per sq. in., E. L. 66,230 lbs. per sq. in., elong. 19 per cent. in 2 in., red. area 30.11 per cent.

FIG. 56. RAIL 10, ETCHED WITH PICRIC ACID.

FIG. 57. RAIL 10, AT TOP OF HEAD.

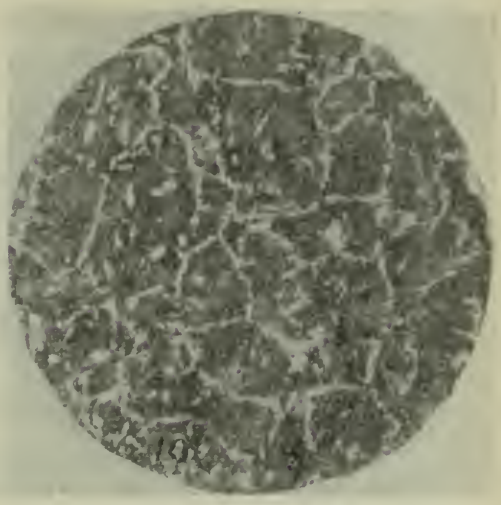


FIG. 58. RAIL 10, ¼ IN. BELOW TOP.

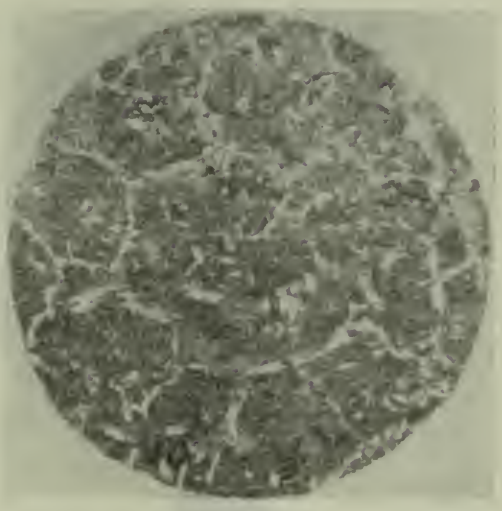


FIG. 59. RAIL 10, ½ IN. BELOW TOP.

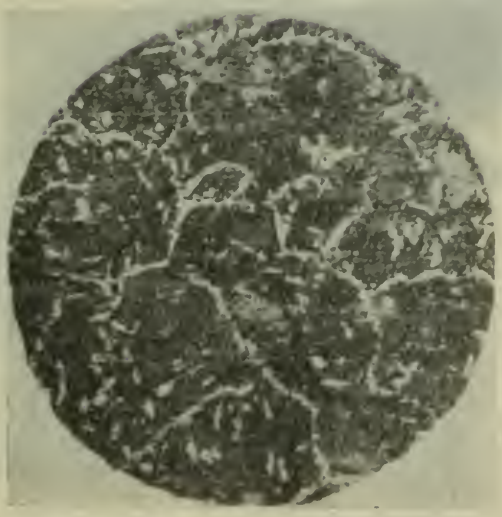


FIG. 60. RAIL 10, ¾ IN. BELOW TOP.

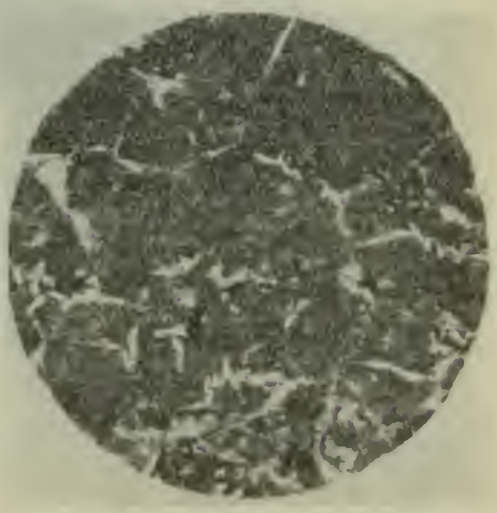


FIG. 61. RAIL 10, 1 IN. BELOW TOP.

MICROPHOTOGRAPHS OF RAIL 10, MAGNIFIED ABOUT 65 DIAMETERS.

RAIL 11.

Carnegie 85-lb. A. S. C. E. section, heat 10639, rolled March, 1899. Laid May, 1899, on straight line, and removed August 4, 1910. In service 11 years.

C .579, Mn 1.04, P .094, Si .149, T. S. 121,650 lbs. per sq. in., E. L. 88,840 lbs. per sq. in., elong. 16 per cent. in 2 in., red. area 22.21 per cent.

FIG. 62. RAIL 11, ETCHED WITH PICRIC ACID.

FIG. 63. RAIL 11, AT TOP OF HEAD.

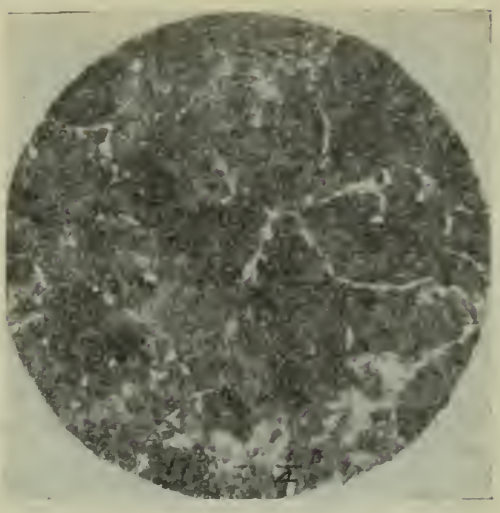


FIG. 64. RAIL 11, ¼ IN. BELOW TOP.

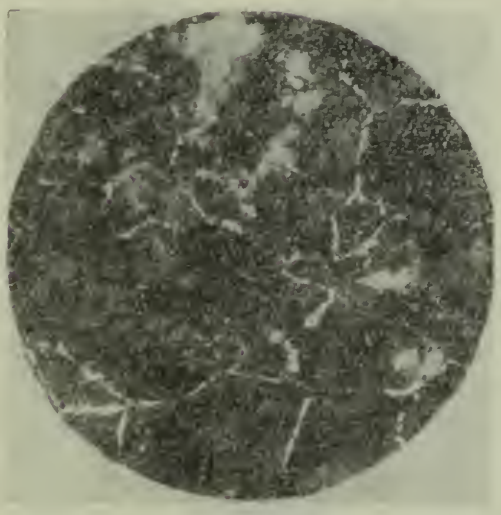


FIG. 65. RAIL 11, ½ IN. BELOW TOP.

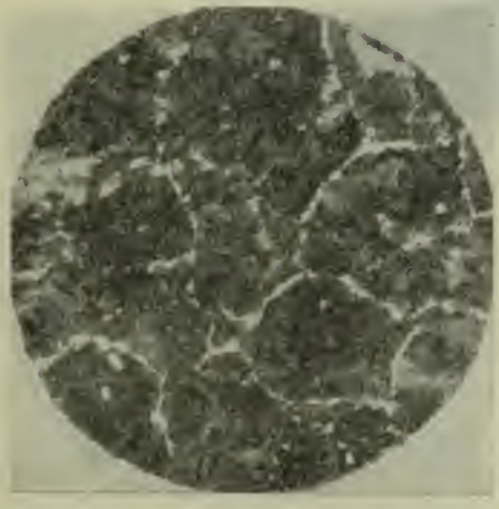


FIG. 66 RAIL 11, ¾ IN. BELOW TOP.

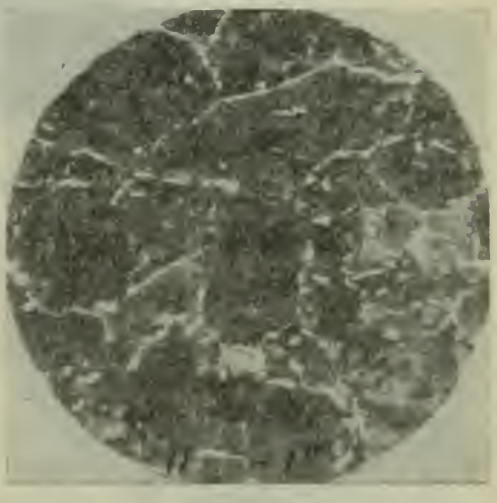


FIG. 67. RAIL 11, 1 IN. BELOW TOP.

MICROPHOTOGRAPHS OF RAIL 11, MAGNIFIED ABOUT 65 DIAMETERS.

RAIL 12.

Illinois, South Works, 85-lb. P. R. R. section, rolled in November, 1894. Laid January, 1895, on straight line, removed July 18, 1910. In service 15½ years.

C .476, Mn 1.06, P .091, Si .133, T. S. 113,450 lbs. per sq. in., E. L. 82,160 lbs. per sq. in., elong. 6.5 per cent. in 2 in., red. area 4.75 per cent.

FIG. 68. RAIL 12, ETCHED WITH PICRIC ACID.

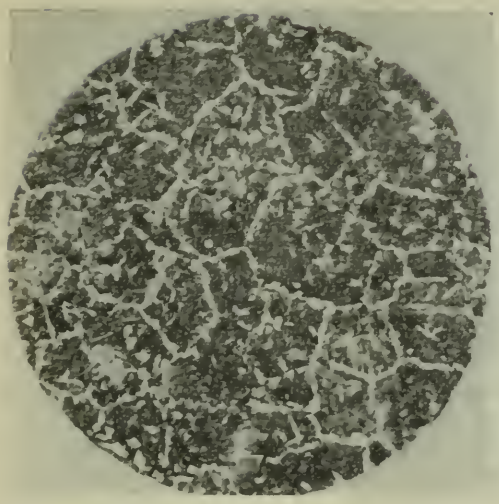


FIG. 69. RAIL 12, AT TOP OF HEAD.

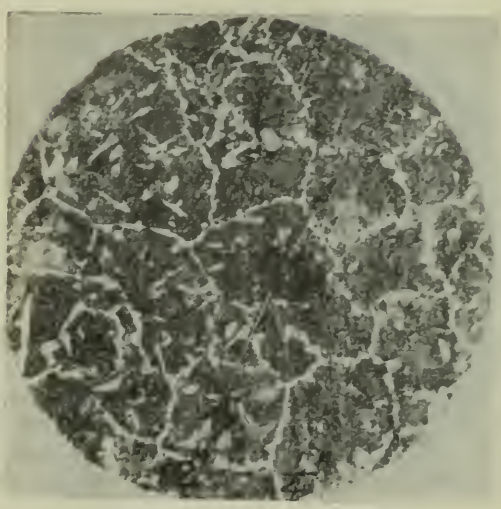


FIG. 70. RAIL 12, ¼ IN. BELOW TOP.

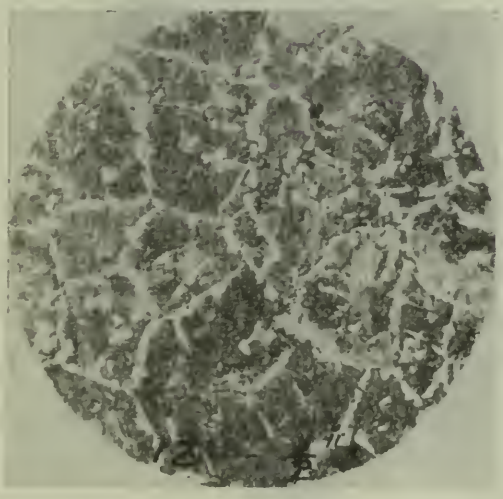


FIG. 71. RAIL 12, ½ IN. BELOW TOP.

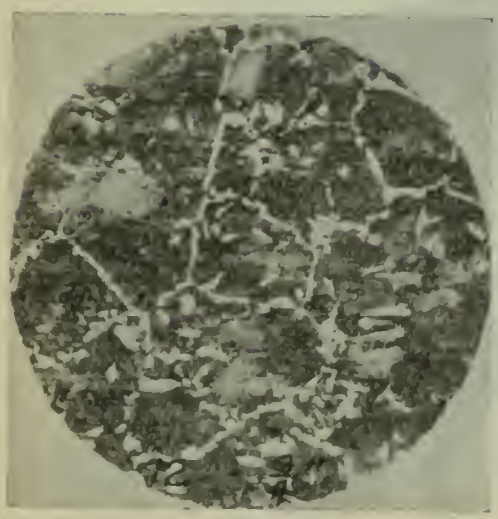


FIG. 72 RAIL 12, ¾ IN. BELOW TOP.

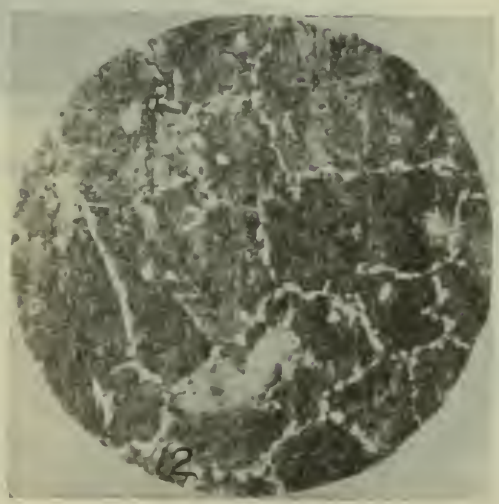


FIG. 73. FAIL 12, 1 IN. BELOW TOP.

MICROPHOTOGRAPHS OF RAIL 12, MAGNIFIED ABOUT 65 DIAMETERS.

RAIL 13.

Carnegie 85-lb. P. R. R. section, rolled December, 1892. Laid January, 1893, on straight line, removed July 26, 1910. In service 17½ years. C .493, Mn 1.06, P .126, Si .149, T. S. 116,510 lbs. per sq. in., E. L. 79,720 lbs. per sq. in., elong. 18 per cent. in 2 in., red. area 26.39 per cent.

FIG. 74. RAIL 13, ETCHED WITH PICRIC ACID.

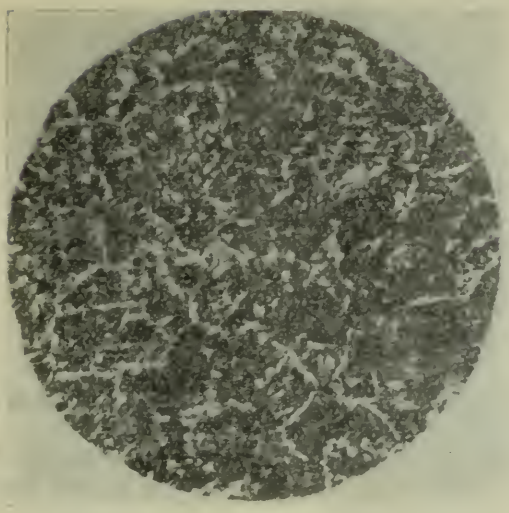


FIG. 75. RAIL 13, AT TOP OF HEAD.

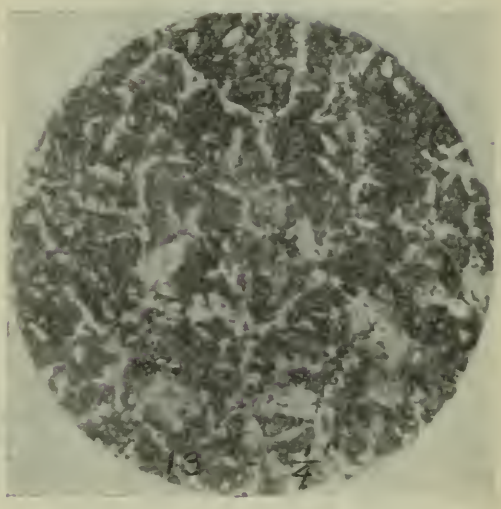


FIG. 76. RAIL 13, ¼ IN. BELOW TOP.

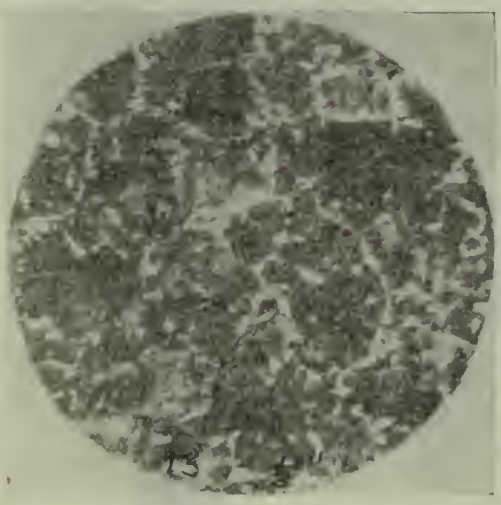


FIG. 77. RAIL 13, ½ IN. BELOW TOP.

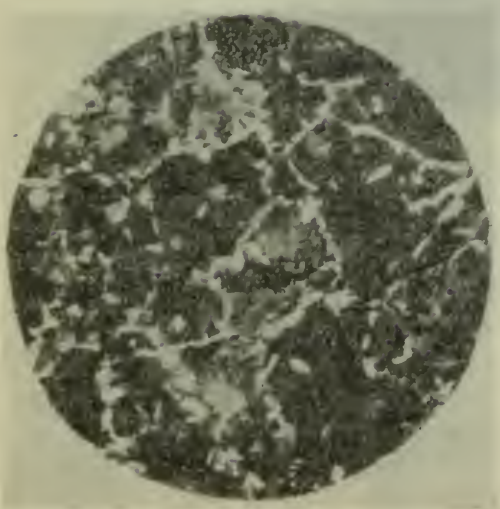


FIG. 78. RAIL 13, ¾ IN. BELOW TOP.

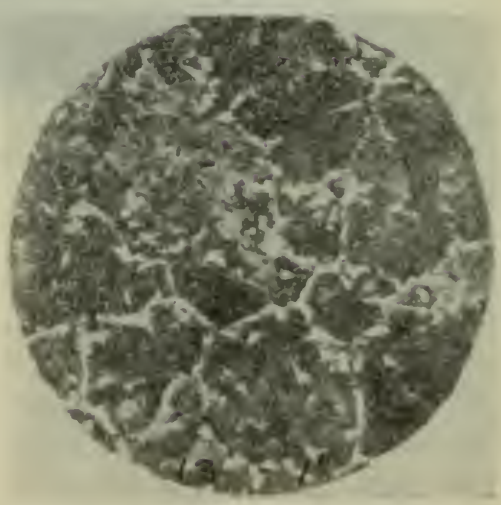


FIG. 79. RAIL 13, 1 IN. BELOW TOP.

MICROPHOTOGRAPHS OF RAIL 13, MAGNIFIED ABOUT 65 DIAMETERS.

RAIL 14.

Carnegie 85-lb. A. S. C. E. section, rolled March, 1899. Laid April, 1899, on straight line, removed March, 1910. In service 11 years.

C .591, Mn .78, P .119, Si .079, T. S. 117,540 lbs. per sq. in., E. L. 78,730 lbs. per sq. in., elong. 4 per cent. in 2 in., red. area 5.57 per cent.

FIG. 80. RAIL 14, ETCHED WITH PICRIC ACID.

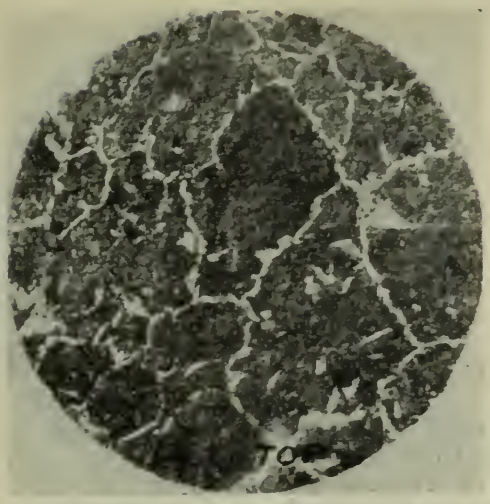


FIG. 81. RAIL 14, AT TOP OF HEAD.

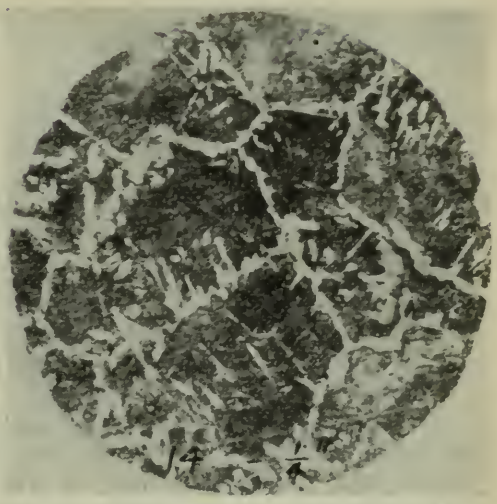


FIG. 82. RAIL 14, ¼ IN. BELOW TOP.

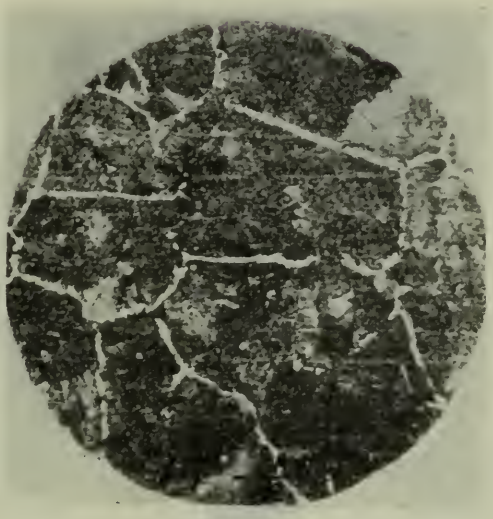


FIG. 83. RAIL 14. ½ IN. BELOW TOP.

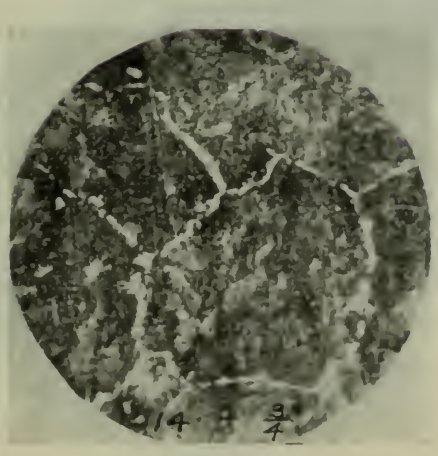


FIG. 84 RAIL 14, ¾ IN. BELOW TOP.

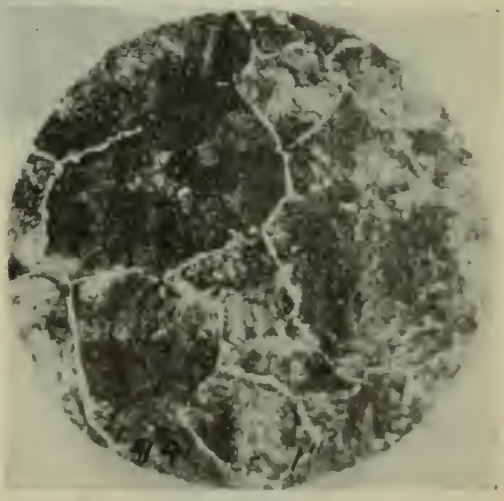


FIG. 85. RAIL 14, 1 IN. BELOW TOP.

MICROPHOTOGRAPHS OF RAIL 14, MAGNIFIED ABOUT 65 DIAMETERS.

RAIL 15.

Carnegie 85-lb. A. S. C. E. section, rolled March 1899. Laid May, 1899, on straight line; removed July 29, 1910. In service 11 years.

C .558, Mn .96, P .101, Si .118, T. S. 118,440 lbs. per sq. in., E. L. 83,850 lbs. per sq. in., elong. 15 per cent. in 2 in., red. area 19 per cent.

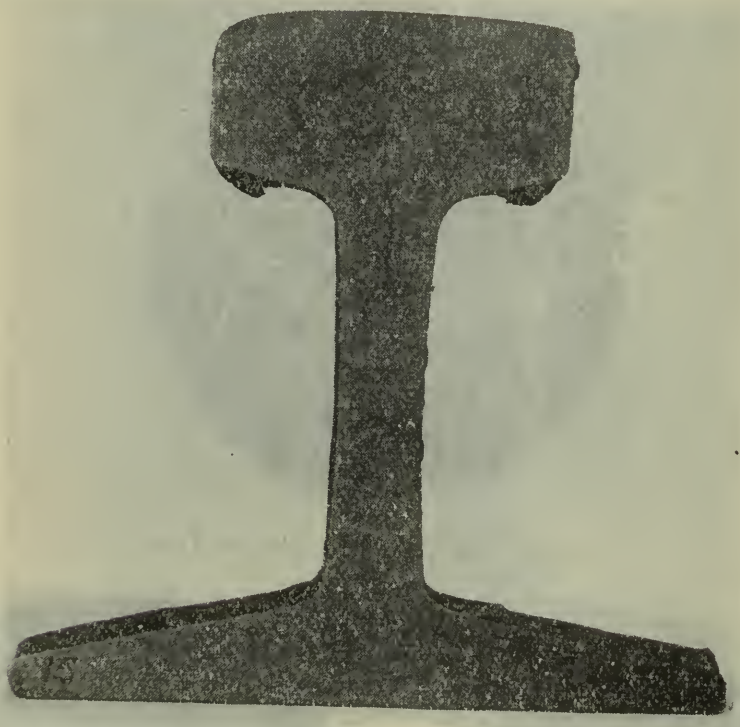


FIG. 86. RAIL 15, ETCHED WITH PICRIC ACID.

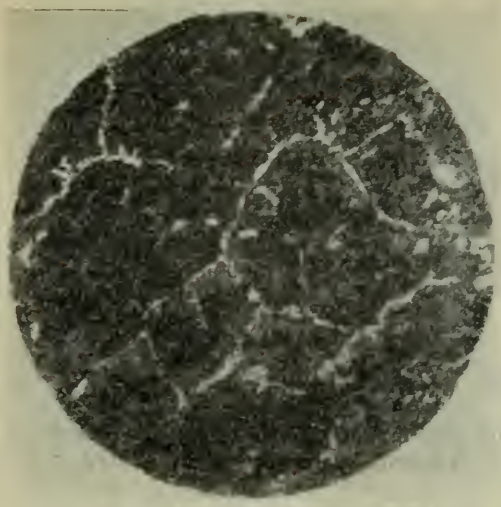


FIG. 87. RAIL 15, AT TOP OF HEAD.

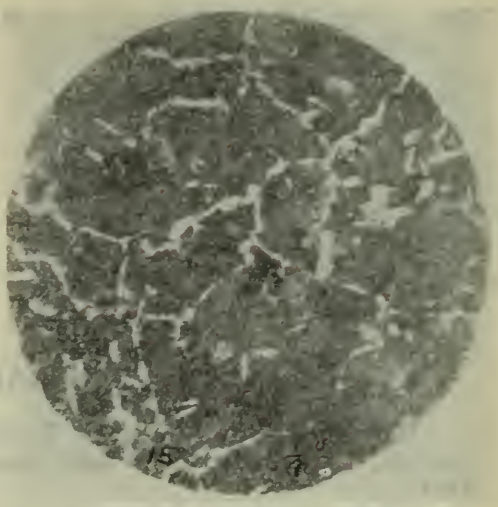


FIG. 88. RAIL 15, ¼ IN. BELOW TOP.

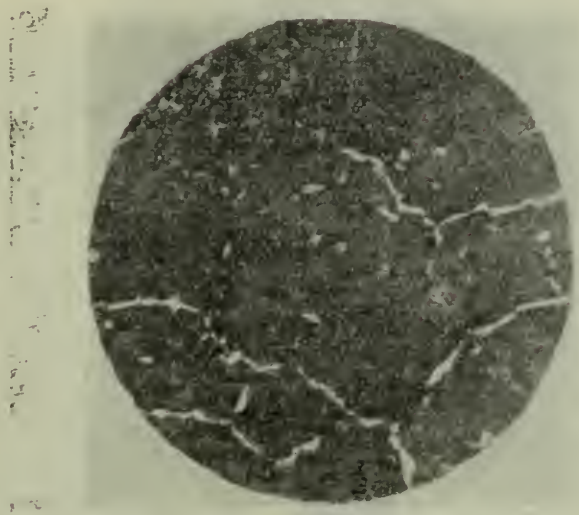


FIG. 89. RAIL 15, ½ IN. BELOW TOP.

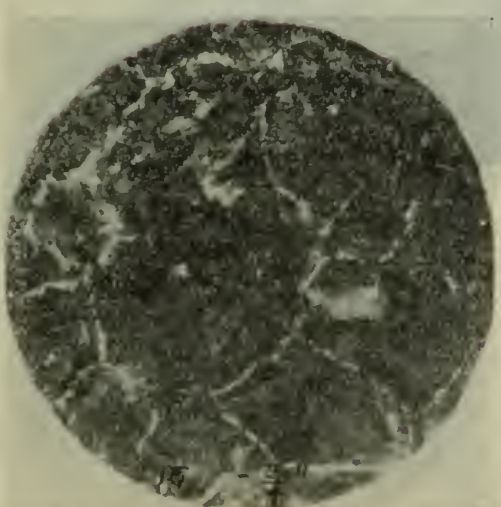


FIG. 90. RAIL 15, ¾ IN. BELOW TOP.

FIG. 91. RAIL 15, 1 IN. BELOW TOP.

MICROPHOTOGRAPHS OF RAIL 15, MAGNIFIED ABOUT 65 DIAMETERS.

RAIL 16.

Carnegie 85-lb. A. S. C. E. section, rolled November, 1902. Laid August, 1903, on straight line; removed August 19, 1910. In service 7 years.

C .515, Mn 1.08, P .113, Si .135, T. S. 117,580 lbs. per sq. in., E. L. 85,580 lbs. per sq. in., elong. 18.5 per cent. in 2 in., red. area 28.43 per cent.

FIG. 92. RAIL 16, ETCHED WITH PICRIC ACID.

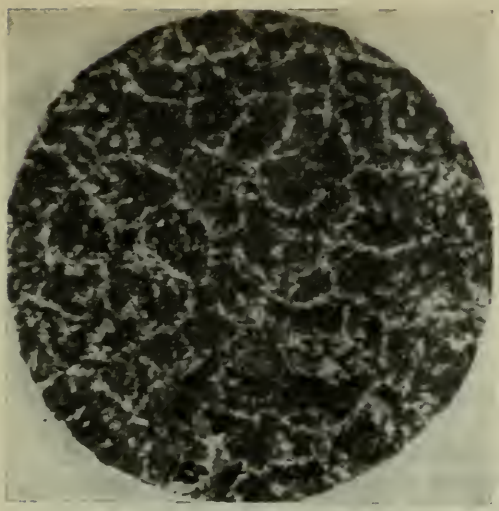


FIG. 93. RAIL 16, AT TOP OF HEAD.

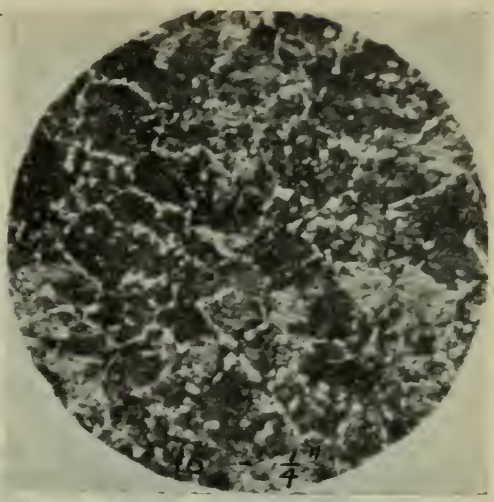


FIG. 94. RAIL 16, ¼ IN. BELOW TOP.

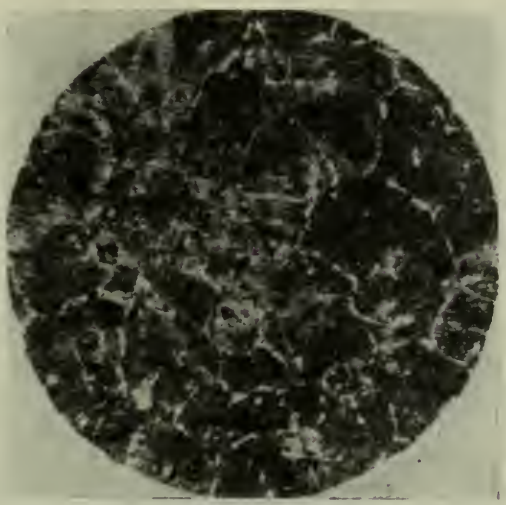


FIG 95. RAIL 16, ½ IN. BELOW TOP.

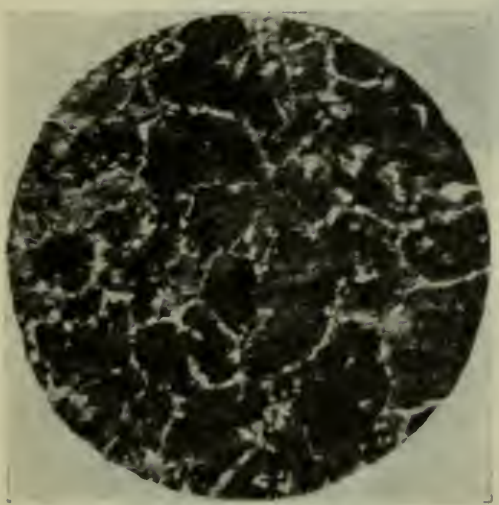


FIG. 96. RAIL 16, ¾ IN. BELOW TOP.

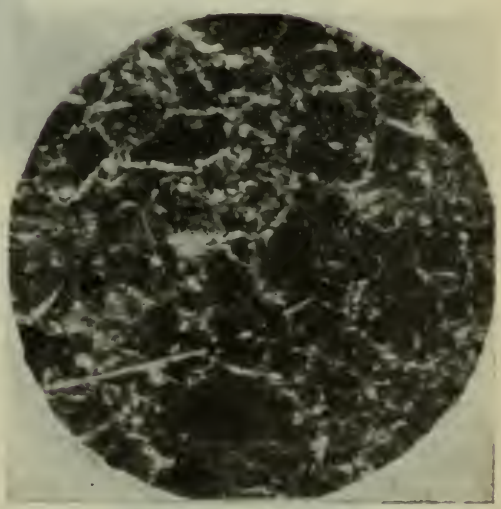


FIG. 97. RAIL 16, 1 IN. BELOW TOP.

MICROPHOTOGRAPHS OF RAIL 16, MAGNIFIED ABOUT 65 DIAMETERS.

RAIL 17.

Carnegie 85-lb. A. S. C. E. section, rolled January, 1903. Laid February, 1903, on straight line; removed August 20, 1910. In service 7 years. C .476, Mn .79, P .096, Si .056, T. S. 102,900 lbs. per sq. in., E. L. 74,940 lbs. per sq. in., elong. 23.5 per cent. in 2 in., red. area 38.82 per cent.

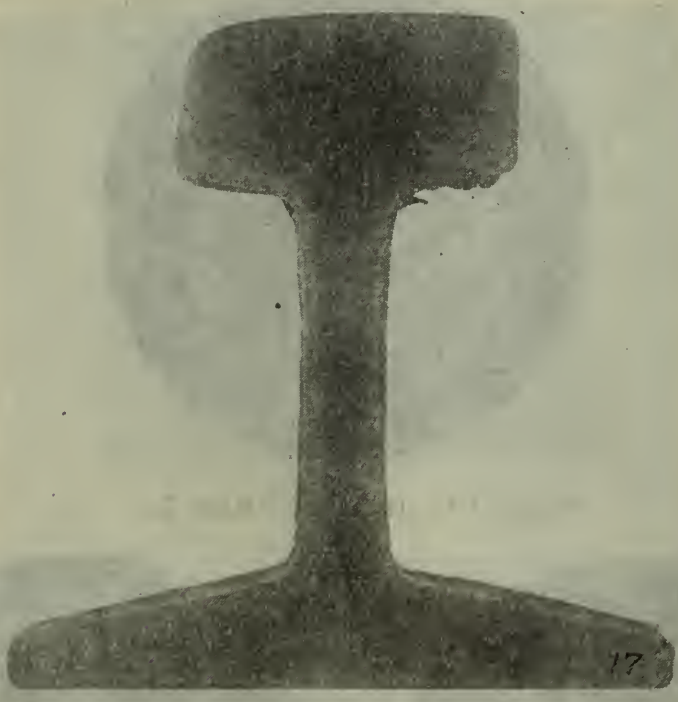


Fig. 98. Rail 17, Etched with Picric Acid.

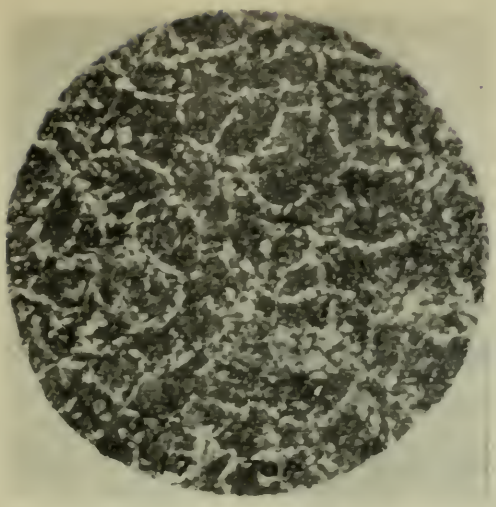


FIG 99. RAIL 17, AT TOP OF HEAD.

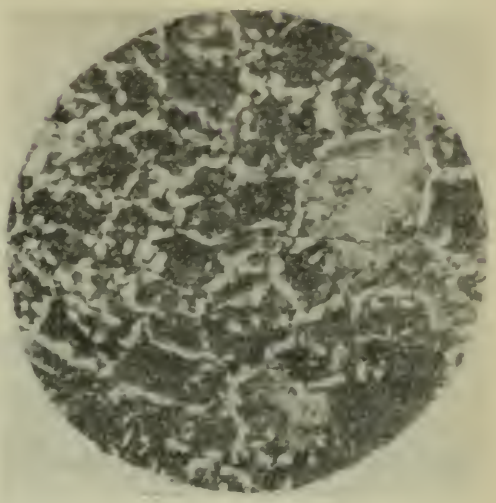


FIG. 100. RAIL 17, ¼ IN. BELOW TOP.

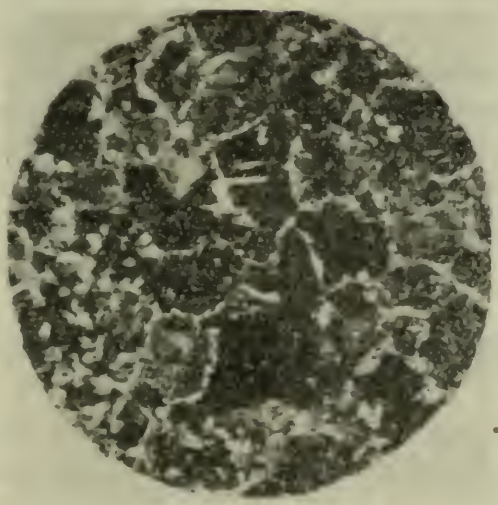


FIG. 101. RAIL 17, ½ IN. BELOW TOP.

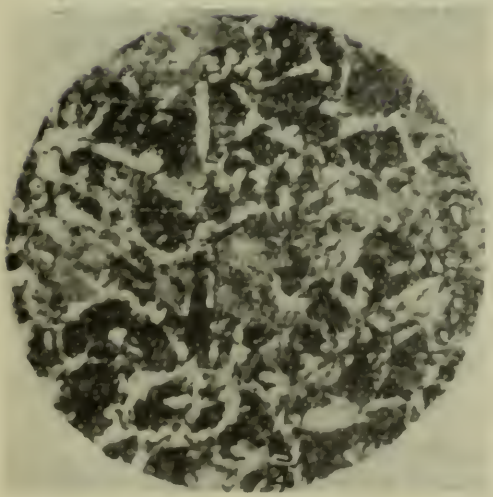


FIG. 102. RAIL 17, ¾ IN. BELOW TOP.

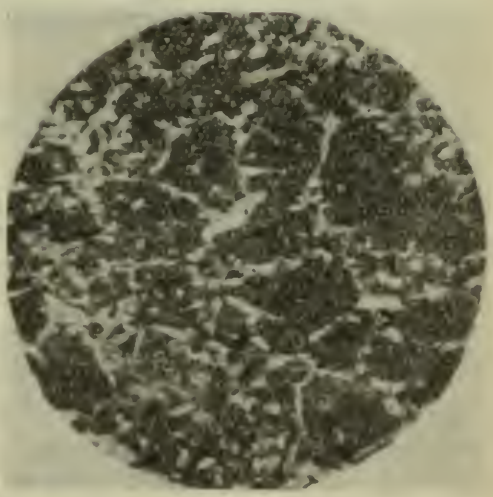


FIG. 103. RAIL 17, 1 IN. BELOW TOP.

MICROPHOTOGRAPHS OF RAIL 17, MAGNIFIED ABOUT 65 DIAMETERS

REPORT OF COMMITTEE IV—ON RAIL.

To the Members of the American Railway Engineering Association:

The Committee on Rail submits, for your information, the Rail Failure Statistics for the year ending October 31, 1910. The work of collecting and compiling these statements, as well as the study of the statistics, was done by Mr. Cushing. The work entailed in compiling and digesting the statistics is quite large. After the receipt of the various reports, a great deal of correspondence was necessary to supply small omissions or clear up uncertainties, all of which required time, with the result that it has taken until the middle of June to finish the work.

The Committee decided not to publish all of the detail statements submitted. These can be secured, upon request to the Secretary, by anyone desiring to make use of them.

RAIL FAILURE STATISTICS FOR ONE YEAR ENDING OCTOBER 31, 1910.

The responses to the American Railway Engineering Association circular have been much more complete than before and show that the majority of the railroads are now keeping a record of their rail failures. Answers were received from 125 companies, 42 of whom either have no information to furnish or the reports were too incomplete to be of any service. Eighty-three companies furnished statistics of failures relating to 11,759,039 tons of rail.

The report consists of the following divisions:

(1) A tabulation of the information received from each company, pp. 1 to 63.
(2) A summary by sections, weights and kinds of steel, pp. 64 to 71.
(3) A tabulation of data for Diagrams 1 to 5, pp. 72 to 86.
(4) A report of failures classified according to the position in the ingot, pp. 87 to 141.
(5) A report on the comparative wear of special rails, pp. 142 to 162.
(6) Diagrams 1, 2, 3, 4 and 5, showing the comparison of failures graphically for different studies.

These details will not be printed with this digest, but can be procured from the Secretary by anyone desiring them.

TABLE 1—TABULATED STATEMENT OF RAILS HAVING NO FAILURES.

Weight per Yd.	Section	Kind of Steel	Manufacturer	Year	Specified Chemical Composition						Railroad
					C.	P.	Mn.	Si.	S.		
100	A. R. A.-A....	Bessemer.....	Illinois.....	1910	.....	.....	.....	.....	.....	.....	Chicago & Alton.
100	A. R. A.-B....	Bessemer.....	Maryland.....	1910	.50	.06	.98	.06	.06	.....	Chesapeake & Ohio
100	A. S. C. E.....	Bessemer.....	Cambria.....	1903–04	.40 .55	.07	1.20	.....	.....	.....	Pennsylvania Lines—N. W. S.
100	A. R. A.-B....	Bessemer.....	Illinois.....	1909	.47	.09	.93	.10	.05	.....	Chesapeake & Ohio
90	A. R. A.-A....	Bessemer.....	Illinois.....	1910	.55 .65	.085	.80 1.05	.20	.....	.....	Oregon Short Line
90	A. R. A.-B....	Bessemer.....	Illinois.....	1909	.45 .55	.10	.84 1.14	.20	.....	.....	Copper Range
90	C. S.....	Bessemer.....	Maryland.....	1905	.60	.085	.90	.20	.075	.....	Morgan's Louisiana & Texas
85	A. S. C. E.....	Bessemer.....	National.....	1900	.....	.....	.....	.....	.....	.....	Pennsylvania Lines—S. W. S.
85	A. S. C. E.....	Bessemer.....	Illinois.....	1903–06	.53	.10	.95	.20	.....	.....	Toledo, Peoria & Western
85	P. S.....	Bessemer.....	Illinois.....	1909	.45 .55	.10	.80 1.20	.05 .20	.....	.....	Pennsylvania Lines—N. W. S.
85	P. S.....	Bessemer.....	Carnegie.....	1910	.45 .55	.10	.80 1.20	.05 .20	.....	.....	Vandalia
80	A. R. A.-A....	Bessemer.....	Illinois.....	1904–10	.....	.....	.....	.....	.....	.....	Chicago & Alton
80	A. R. A.-A....	Bessemer.....	Illinois.....	1909	.45	.10	.90	.20	.....	.....	Toledo, Peoria & Western
80	A. R. A.-A....	Bessemer.....	Illinois.....	1910	.....	.....	.....	.....	.....	.....	Toledo, Peoria & Western
80	A. S. C. E.....	Bessemer.....	Carnegie.....	1902	.43 .53	.10	.80 1.10	.20	.....	.....	Central of Georgia
80	A. S. C. E.....	Bessemer.....	Illinois.....	1905	.55	.085	.90	.20	.075	.....	Galveston, Harrisburg & San Antonio
80	A. S. C. E.....	Bessemer.....	Lackawanna	1910	.43 .53	.10	.90 1.10	.13 .20	.075	.....	Lake Shore & Michigan Southern
80	A. S. C. E.....	Bessemer.....	Algoma.....	1902	.446	.097	.901	.107	.052	.....	Michigan Central
80	A. S. C. E.....	Bessemer.....	Lackawanna	1906–10	.43 .58	.10	.90 1.10	.13 .20	.....	.....	Munising
80	A. S. C. E.....	Bessemer.....	Lackawanna.....	1907–10	.43 .58	.10	.75 1.10	.20	.....	.....	Munising
80	A. S. C. E.....	Bessemer.....	National	1901–02	.43 .53	.10	.80 1.10	.20	.....	.....	Rock Island
80	A. S. C. E.....	Bessemer.....	Illinois.....	1903–05	.....	.....	.....	.....	.....	.....	St. Jos. & Grand Island
80	A. S. C. E.....	Bessemer.....	Col. Fuel & Iron.....	1906	.....	.....	.....	.....	.....	.....	St. Louis, Rocky Mountain & Pacific
75	C. S.....	Bessemer.....	Illinois.....	1910	.....	.....	.....	.....	.....	.....	Northwestern Pacific
75	C. S.....	Bessemer.....	Illinois.....	1907–10	.....	.....	.....	.....	.....	.....	St. Jos. & Grand Island

100	A. R. A.-A....	Open-Hearth..	Maryland.....	1910	.62 .75	.04	.60 .90	.20	.....	.....	Central R. R. of New Jersey
100	A. R. A.-A....	Open-Hearth..	Illinois-Gary.....	1910	.63 .76	.04	.60 .90	.10 .20	.....	.....	Rock Island
100	A. R. A.-B....	Open-Hearth..	Bethlehem.....	1910	.65 .80	.04	.75 1.00	.05 .20	.....	.....	Baltimore & Ohio
100	A. R. A.-B....	Open-Hearth..	Cambria.....	1910	.65 .80	.04	.75 1.00	.05 .20	.....	.....	Baltimore & Ohio
100	A. R. A.-B....	Open-Hearth..	Maryland.....	1910	.62 .75	.04	.75 1.00	.05 .20	.....	.....	Baltimore & Ohio
100	P. S.....	Open-Hearth..	Carnegie.....	1909	.62 .75	.04	.80	.20	.....	.....	Pennsylvania Lines—S. W. S.
90	A. R. A.-A....	Open-Hearth..	Bethlehem.....	1910	.59 .72	.04	.60 .90	.20	.....	.....	Chicago, Burlington & Quincy
90	A. R. A.-A....	Open-Hearth..	Tenn. C. I. & R. R..	1910	.55 .65	.085	.80 1.10	.20	.075	.....	Houston & Texas Central
90	A. R. A.-A....	Open-Hearth..	Tenn. C. I. & R. R..	1910	.63 .76	.04	.70 1.00	.20	.....	.....	Morgan's Louisiana & Texas
90	A. R. A.-A....	Open-Hearth..	Col. Fuel & Iron.....	1910	.....	.....	.....	.....	.....	.....	Oregon R. R. & Navigation Co.
90	A. R. A.-A....	Open-Hearth..	Tenn. C. I. & R. R..	1910	.63 .76	.04	.70 1.00	.20	.....	.....	Texas & New Orleans
90	A. R. A.-B....	Open-Hearth..	Bethlehem.....	1909	.65	.03	.78	.14	.05	.....	Chesapeake & Ohio
90	A. S. C. E....	Open-Hearth..	Carnegie.....	1910	.62 .75	.04	.80 1.05	.....	.....	.....	Lehigh Valley
90	A. S. C. E....	Open-Hearth..	Pennsylvania.....	1910	.70 .85	.03	.60 .90	.20	.....	.....	Philadelphia & Reading
90	C. S.....	Open-Hearth..	Tenn. C. I. & R. R..	1908-09	.63 .76	.04	.70 1.00	.20	.....	.....	Illinois Centra
90	G. N.....	Open-Hearth..	Lackawanna.....	1910	.68	.04	.70 1.00	.20	.....	.....	Great Northern
90	G. N.....	Open-Hearth..	Pennsylvania.....	1908-09	.59 .72	.04	.60 .90	.20	.....	.....	Great Northern
85	A. S. C. E....	Open-Hearth..	Tenn. C. I. & R. R..	1909-10	.55 .68	.06	.60 .90	.20	.....	.....	Atlantic Coast Line
85	A. S. C. E....	Open-Hearth..	Maryland.....	1910	.55 .68	.06	.60 .90	.20	.....	.....	Atlantic Coast Line
85	A. S. C. E....	Open-Hearth..	Tenn. C. I. & R. R..	1909	.59 .72	.04	.60 .90	.20	.06	.....	Carolina, Clinchfield & Ohio
85	A. S. C. E....	Open-Hearth..	Illinois.....	1909-10	.59 .72	.04	.60 .90	.10 .20	.....	.....	Chicago & Eastern Illinois
85	P. S.....	Open-Hearth..	Cambria.....	1910	.62 .75	.04	.80	.05 .20	.....	.....	Grand Rapids & Indiana
80	A. S. C. E....	Open-Hearth..	Col. Fuel & Iron.....	1909	.64	.029	.43	.048	.045	.....	Colorado Midland
80	A. S. C. E....	Open-Hearth...	Pennsylvania.....	1910	.71 .85	.008 .039	.61 .84	.05 .15	.029 .076	.....	New York, New Naven & Hartford
75	A. S. C. E....	Open-Hearth..	Illinois.....	1909	.....	.....	.....	.....	.....	.....	Northwestern Pacific
75	C. S.....	Open-Hearth..	Bethlehem.....	1909	.45	.025	.90	.097	.035	.....	Oregon R. R. & Navigation Co.
100	A. R. A.-A....	Ferro Titanium Bessemer.....	Lackawanna.....	1910	.50 .60	.10	.84 1.14	.20	.....	F. T. .4	Central R. R. of New Jersey

TABLE 2—TABULATED STATEMENT OF LARGEST NUMBER OF FAILURES.

	No. of Failures per 10,000 Tons Laid	Wt. per yd.	Section	Kind of Steel	Manufacturer	Year	Specified Chemical Composition						Predominant Failures	Railroad
							C	P	Mn	Si	S			
1	304	100	A. R. A.-B.	Bess.....	Carnegie.....	1908–10	.45 .55	.10	.85 1.20	.05 .20	.075	.....	Crshd. Hd.....	Baltimore & Ohio.
2	277	90	A. R. A.-B.	O.-H.....	Bethlehem....	1908–10	.65 .80	.04	.75 1.00	.05 .20	.....	.....	Sp. & Cr. Hds.	Baltimore & Ohio.
3	270	85	A. S. C. E.	Bess.....	Carnegie.....	1901–02	.43 .53	.10	.80 1.10	.20	.....	.....	Split Hds.....	Illinois Central.
4	251	85	C. B. & Q..	Bess.....	Carnegie.....	1906–07	.48 .58	.10	.80 1.10	.20	.....	.....	Split Hds.....	C. B. & Q.
5	237	90	A. S. C. E.	Bess.....	Carnegie.....	1905–10	.50 .60	.10	.80 1.10	.20	.....	.....	Breakages.....	C. C. C. & St. L.
6	229	100	A. S. C. E.	Bess.....	Illinois.....	1907	.48 .58	.10	.80 1.10	.20	.....	.....	Split Hds.....	C. B. & Q.
7	220	85	A. S. C. E.	Bess.....	Carnegie.....	1906–07	.48 .58	.10	.80 1.10	.20	.....	.....	Breakages.....	Northern Pacific.
8	218	75	A. S. C. E.	Bess.....	Illinois.....	1909	.40 .50	.10	.75 1.05	.20	.....	.....	Breakages.....	Chi., Ind. & Lou.
9	212	75	A. S. C. E.	Bess.....	Lackawanna...	1904–10	.43 .53	.10	.80 1.10	.20	.....	.....	Breakages.....	Boston & Maine.
10	190	90	A. S. C. E.	Bess.....	Lackawanna...	1906	.50 .60	.10	.80 1.10	.20	.....	.....	Sp. & Cr. Hds..	C. C. C. & St. L.
11	189	100	P. R. R....	Bess.....	Maryland.....	1889–09	.50	.08	1.00	.13	.....	.....	Breakages.....	P. R. R.
12	186	80	A. S. C. E.	Bess.....	Lackawanna...	1901–06	.50 .60	.085	.80 1.10	.20	.075	.....	Brk. & Sp. Hds.	Union Pacific.
13	177	90	A. R. A.-A.	Bess.....	Carnegie.....	1909–10	.45 .55	.10	.80 1.20	.05 .20	.....	.....	Crshd. Hd.....	Baltimore & Ohio
14	170	90	A S. C. E.	O.-H.....	Bethlehem....	1908–09	.57	.031	.82	.....	.....	.....	Breakages.....	Cen. R. R. of N. J.
15	168	85	P. S.....	Bess.....	Carnegie.....	1909–10	.45 .55	.10	.80 1.20	.05 .20	.....	.....	Sp. & Cr. Hds..	Penna. Lines—N. W. S.
16	163	85	A. S. C. E.	Bess. Nickel	Carnegie.....	1903	.44	.09	.80	.10	.03	N. 342	Sp. & Cr. Hds..	Penna. Lines.
17	159	85	A. S. C. E.	Bess.....	Carnegie.....	1905–09	.43 .53	.095 .10	.95 1.10	.084 .20	.039	.....	Sp. & Cr. Hds..	Chic. & East. Ill
18	158	80	A. S. C. E.	Bess.....	Lackawanna...	1906–09	.43 .55	.10	.75 1.10	.20	.075	.....	Breakages..... Sp. Hd. & Web..	Erie.
19	154	90	A. S. C. E.	Bess.....	Cambria.....	1907	.54 .64	.10	.90 1.15	.20	.....	.....	Split Hds..... Broken Base....	Cen. R. R. of N. J.
20	148	80	A. S. C. E.	O.-H.....	Dom. I. & S...	1906–08	.56 .75	.06	.75 1.05	.075 .20	.06	.....	.....	Canadian Pacific.

21	147	85	A. S. C. E.	Bess.....	Illinois.....	1903-08	.43 .58	.10	.80 1.10	.20	.....	.....	Breakages..... Broken Base....	Northern Pacific.
22	146	90	A. S. C. E.	Bess.....	Carnegie.....	1906	.54 .64	.10	1.05 1.30	.20	.....	.....	Split Heads.....	Cen. R. R. of N. J.
23	137	80	A. S. C. E.	Bess.....	Carnegie.....	1899-08	.43 .58	.10	.80 1.10	.20	.....	.....	Sp. & Cr. Hds..	C. C. C. & St. L.
24	134	90	A. S. C. E.	O.-H.....	Bethlehem....	1907-10	.70 .80	.04	.80 1.05	.....	.....	.....	Breakages.....	Lehigh Valley.
25	130	90	A. S. C. E.	Bess.....	Illinois.....	1906-10	.45 .58	.10	.80 1.15	.20	.075	.....	Breakages.....	Erie.
26	128	90	A. S. C. E.	Bess.....	Carnegie.....	1902-10	.47 .57	.10	.82 1.10	.20	.075	.....	Split Hds.....	Pittsburg & Lake Erie.
27	127	90	C. S.....	Bess.....	Illinois.....	1906	.50 .60	.10	.80 1.10	.20	.075	.....	Split Hds.....	Oregon Short Line.
28	125	90	A. S. C. E.	Ferro. Tit. Bess.....	Lackawanna...	1909	.45 .55	.10	.85 1.15	.10 .20	.075	F.T. .3	Breakages.....	Erie.
29	124	90	A. S. C. E.	Bess.....	Carnegie.....	1907-10	.50	.10	.98	.103	.05	.....	Crshd. Hds....	Hocking Valley.
30	122	90	A. S. C. E.	Bess.....	Maryland.....	1902-09	.45 .55	.10	.80 1.20	.20	.....	.....	Split Web.....	Lehigh Valley.
31	120	85	P. S.....	O.-H.....	Illinois-Gary...	1909	.70 .83	.03	.80	.05 .20	.....	.....	Split Hds.....	Penna. Lines—S. W. S.
32	116	90	A. S. C. E.	Bess.....	Carnegie	1900-09	.45 .55	.10	.80 1.20	.20	.....	.....	Split Hds.....	Lehigh Valley.
33	114	90	C. S.....	Bess.....	Carnegie.....	1906-09	.50 .60	.10	.80 1.10	.20	.075	.....	Split Hds.....	Union Pacific.
34	113	100	A. R. A.-A.	Bess.....	Carnegie.....	1909	.45 .55	.10	.80 1.20	.05 .20	.....	.....	Split Hds.....	Penna. Lines—S. W. S.
35	112	85	A. R. A.-A.	Bess.....	Illinois.....	1908	.43 .53	.10	.80 1.10	.20	.....	.....	Breakages..... Crshd. Hd.....	A. T. & S. F.
36	105	85	A. S. C. E.	Bess.....	Carnegie.....	1899-08	.45 .55	.10	.80 1.20	.05 .20	.....	.....	Crshd. Hds....	Vandalia.
37	100	85	A. S. C. E.	Bess.....	Lackawanna...	1906-09	.43 .58	.10	.80 1.10	.20	.....	.....	Breakages.....	Northern Pacific.
38	100	90	A. S. C. E.	Bess.....	Carnegie.....	1905-10	.53	.10	.80 1.10	.20	.....	.....	Sp. & Cr. Hds..	Wheeling & Lake Erie.
39	99	90	A. S. C. E.	Bess.....	Carnegie.....	1906-10	.45 .58	.10	.80 1.15	.20	.075	.....	Flow of Metal..	Erie.
40	97	90	A. S. C. E.	Bess.....	Maryland.....	1906-07	.....	.....	.....	.....	.....	.....	Flow of Metal..	Delaware & Hudson.
41	97	80	A. S. C. E.	Bess.....	Carnegie.....	1904-05	.50 .60	.085	.80 1.10	.20	.075	.....	Split Hds.....	Union Pacific.
42	97	90	C. S.....	Bess.	Illinois.....	1908-09	.55 .65	.085	.80 1.05	.20	.....	.....	Sp. & Cr. Hds..	Illinois Central.
43	92	100	A. S. C. E.	Bess.....	Lackawanna...	1905-10	.45 .55	.10	.90 1.10	.20	.....	.....	Sp. & Cr. Hds..	LakeShore&Mich.Sou.
44	91	80	A. S. C. E	O.-H.....	Dom. I. & S...	1906-09	.55 .65	.065	.80 1.10	.20	.069	.....	Breakages.....	Grand Trunk.

TABLE 2—TABULATED STATEMENT OF LARGEST NUMBER OF FAILURES—CONTINUED.

	No. of Failures per 10,000 Tons Laid	Wt. per yd.	Section	Kind of Steel	Manufacturer	Year	Specified Chemical Composition						Predominant Failures	Railroad
							C	P	Mn	Si	S			
45	91	90	A. R. A.-A.	O.-H.....	Illinois-Gary..	1909	.....	.....	.....	.....	.....	.....	Split Hds.....	Southern Pacific.
46	89	80	A. S. C. E.	Bess.....	Maryland.....	1906–07	.....	.....	.....	.....	.....	.....	Breakages.....	Delaware & Hudson.
47	86	90	A. S. C. E.	Bess.....	Lackawanna...	1900–10	.45 .55	.10	.80 1.20	.20	.....	.....	Crshd. Hd.....	Lehigh Valley.
48	84	100	A. S. C. E.	Bess.....	Carnegie.....	1902	.40 .55	.07	1.20	.....	.....	.....	Sp. & Cr. Hds..	Penna. Lines—S. W. S.
49	82	100	A. S. C. E.	Bess.....	Carnegie.....	1901–07	.40 .55	.07	1.20	.....	.....	....	Sp. & Cr. Hds..	Penna. Lines—N. W. S.
50	81	90	A. S. C. E.	Bess.....	Illinois.....	1906–10	.50 .60	.10	.80 1.10	.20	.....	.....	Breakages.....	C. C. C. & St. L.
51	80	85	A. S. C. E.	Bess.....	Lackawanna...	1907	.48 .58	.10	.80 1.10	.20	.....	.....	Flow of Metal..	Atlantic Coast Line.
52	79	85	A. S. C. E.	Bess.....	Cambria.....	1901–07	.45 .55	.10	.80 1.20	.05 .20	.....	.....	Sp. & Cr. Hds..	Vandalia.
53	78	85	C. B. & Q...	Bess.....	Illinois.....	1905–08	.48 .58	.10	.80 1.10	.20	.....	.....	Sp. & Cr. Hds..	C. B. & Q.
54	77	90	A. S. C. E.	Bess.....	Maryland.....	1903–09	.45 .60	.10	.90 1.10	.10 .20	.....	.....	Broken Base....	Cen. R. R. of N.J.
55	77	75	C. S.....	Bess.....	Carnegie.....	1905–09	.52 .63	.084 .112	.85 .92	.092 .119	.040 .058	.....	Sp. & Cr. Hds..	Ore. R. R. & Nav. Co.
56	76	90	A. S. C. E.	Bess.....	Cambria.....	1899–09	.45 .55	.10	.80 1.20	.20	.....	.....	Breakages.....	Lehigh Valley.
57	74	90	A. R. A.-B.	Bess.....	Cambria.....	1909–10	.45 .55	.10	.85 1.20	.05 .20	.....	.....	Sp. & Cr. Hds..	Baltimore & Ohio.
58	74	85	A. S. C. E.	Bess.....	Carnegie.....	1908	.48 .58	.10	.80 1.10	.10 .20	.075	.....	Sp. & Cr. Hds..	Carol., Clinch. & Ohio.
59	73	85	A. S. C. E.	Bess.....	Carnegie.....	1899	.43 .53	.10	.80 1.10	.20	.....	.....	Breakages..... Crshd. Hd.....	Boston & Maine.
60	72	80	A. S. C. E.	Bess.....	Carnegie.....	1901–10	.44 .54	.10	.82 1.10	.20	.075	.....	Split Hds.....	Pittsburg & Lake Erie.
61	71	90	A. S. C. E.	Nick. Chr. O.-H.....	Bethlehem....	1909	.50 .60	.04	.60 .90	.20	Nickel 2.00	Chr. .40 .75	Breakages.....	Lehigh Valley.
62	70	80	A. S. C. E.	Bess.....	Lackawanna...	1904–05	.48 .58	.10	.80 1.10	.20	.....	.....	Sp. & Cr. Hds..	C. C. C. & St. L.
63	68	85	A. S. C. E.	Bess.....	Lackawanna...	1904–10	.43 .53	.10	.80 1.10	.20	.....	.....	Breakages.....	Boston & Maine.

64	68	85	A. S. C. E.	Bess	Cambria	1903-08	.40 .55	.10	1.20				Breakages	Grand Rapids & Indiana.
65	67	95	B. & A.	Bess	Bethlehem	1891	.60	.06	.90	.15 .16	.08		Sp. & Cr. Hds.	Boston & Albany.
66	64	80	A. S. C. E.	Bess	Illinois	1896-04	.48	.09	.92	.094			Split Hds	Munising.
67	63	80	Dudley	Bess.	Carnegie	1906	.50	.10	.98	1.03	.05		Breakages Split Web	Hocking Valley.
68	62	80	A. S. C. E.	Bess	Lackawanna	1907	.48 .58	.10	.80 1.10	.20			Sp. & Cr. Hds.	Grand Trunk.
69	62	100	Dudley	Bess	Lackawanna	1904-10	.45 .55	.10	.90 1.10	.13 .20	.075		Sp. & Cr. Hds.	Boston & Albany.
70	61	80	A. S. C. E.	Bess	Colo. F. & I.	1901-06	.45 .55	.085 .10	.80 1.10	.20	.075		Breakages	Oregon Short Line.
71	57	100	A. R. A.-B.	Bess	Carnegie	1908-09	.45 .55	.092	.95	1.02	.04		Crshd. Hd	Bessemer & Lake Erie.
72	57	90	A. S. C. E.	Bess	Cambria	1905-10							Split Hds	Philadelphia & Reading.
73	57	85	P. S.	O.-H.	Illinois-Gary	1909-10	.62 .75	.04	.80	.05 .20			Sp. & Cr. Hds.	Penna. Lines—S. W. S.
74	56	80	A. S. C. E.	Bess	Carnegie	1897-10								Canadian Pacific.
75	56	90	A. S. C. E.	Bess	Lackawanna	1904-07	.54 .65	.10	.90 1.15	.20			Crshd. Hd	Cen. R. R. of N. J.
76	54	100	A. S. C. E.	Bess	Lackawanna	1903-10	.49 .56	.076 .092	.97 1.08	.087 .139	.046 .090	Cu. .088 .223	Split Hds	Michigan Central.
77	54	85	A. S. C. E.	Bess	Carnegie	1901-08	.45 .60	.082 .10	.80 1.10	.20	.044 .053		Sp. & Cr. Hds.	Baltimore & Ohio.
78	53	100	A. S. C. E.	Bess	Cambria	1905-07	.497 .502	.098		.56 .61			Sp. & Cr. Hds.	Baltimore & Ohio.
79	53	75	C. S.	Bess									Sp. & Cr. Hds.	Southern Pacific.
80	53	100	P. S.	O.-H.	Lackawanna	1909-10	.69	.022	.71	.12 .15	.034 .041		Sp. & Cr. Hds. Breakages	P. R. R.
81	52	85	A. R. A.-A.	Bess	Cambria	1903-07	.48 .58	.10	.80 1.05	.20	.075		Breakages	A. T. & S. F.
82	52	100	A. R. A.-A.	Bess	Carnegie	1909	.46 .56	.10	.80 1.20	.05 .20			Split Hds	Baltimore & Ohio.
83	51	90	A. S. C. E.	Bess	Carnegie	1907-10	.45 .55	.10	.84 1.14	.20			Flow of Metal Split Hds	B. R. & P.
84	51	90	C. S.	Bess	Illinois	1906-10	.50 .60	.10	.80 1.10	.20	.075		Split Hds Breakages	Union Pacific.
85	50	100	Dudley	Bess	Lackawanna	1901-09	.40 .70	.10	.85 1.14	.10 .20	.069 .090		Breakages	New York Cent. & H. R.
86	50	90	G. N.	Bess	Cambria	1909	.48	.10	.80 1.10	.20			Sp. & Cr. Hds.	Great Northern.
87	50	85	A. S. C. E.	Bess	Illinois	1898-05	.48 .58	.10	.80 1.10	.20			Sp. & Cr. Hds.	St. Louis & San Francisco
88	50	80	A. S. C. E.	Bess	Car. & Nat.	1902	.466	.094	93	.053	.047		Sp. & Cr. Hds.	Michigan Central.

In Vol. 12, Part 2, page 143, et seq., will be found the drawings of nearly all of the rail sections referred to, an effort having been made to make this collection of drawings as complete as possible, for future reference.

GENERAL SUMMARY (PP. 1 TO 63).

In considering the statistics as tabulated, all lots of less than 1,000 tons have been ignored, as they usually lead to exaggerated results.

The number of failures range from 0 to 1129 per 10,000 tons of new rail laid.

There were no failures reported for the various lots of rail listed in Table 1.

It will be noticed, however, that nearly all of these lots are of the years 1909 and 1910, the rail being thus too new to have begun failing. In the few cases where the rail is of an earlier date, it is quite likely that the poor rails have already been weeded out.

In addition to the above, there are many lots in which there was only one failure, or even but two or three, but to have listed them also would have required too much space.

For these various lots, the prescribed chemical constituents run about as follows:

For P. .10 the C. runs from .43 to .58.
For P. .085 the C. runs from .55 to .65.
For P. .06 the C. runs from .55 to .68.
For P. .04 the C. runs from .63 to .76, and even .80.
For P. .03 the C. runs from .70 to .85.

The 1129 failures per 10,000 tons were of the 90-lb. A.S.C.E. chromium-nickel rail of the year 1909, on the Central Railroad of New Jersey, the chemical composition of which is not given. The rate of failure is higher than ever, and it will be found on page 61 that 70 per cent. of them were breakages and nearly all the rest split heads. The failures are characteristic of this product, the breakages occurring from hair-line cracks, and the "split heads" being longitudinal seams instead of the usual split head. After the first shower after being laid, dark purple stains appear.

In Table 2 the maximum number of failures in diminishing order down to 50 have been listed for convenience in studying the effect of the specified chemical composition, and Table 1 should be considered in connection with it.

We are forced to conclude, after an examination of both tables, that the specified chemical composition does not account for all the differences, although it undoubtedly has its effect and must be kept within certain limits in order to prevent disastrous results.

For instance, why were there fewer failures of 90-lb. A.R.A.-B Cambria rail (No. 57) on the Baltimore & Ohio, or of 100-lb. A.R.A.-B Carnegie (71) on the Bessemer & Lake Erie, than of 100-lb. A.R.A.-B Carnegie rail (1) of the same specified composition on the Baltimore

& Ohio? It is considered possible that the failures of Baltimore & Ohio No. 1 might be due to a small discard, as low as 5 per cent., as a very large percentage occurred in "A" rails.

Again, is C. .65 to .80 too high when P. is .04 for the 90-lb. A.R.A.-B Bethlehem rail (2) on the Baltimore & Ohio? We cannot tell, because there are considerably fewer failures in the case of the 90-lb. A.S.C.E. Bethlehem (24) on the Lehigh Valley, with C. .70 to .80 and P. .04, and indeed with the same composition the Baltimore & Ohio had no failures of their 100-lb. A.R.A.-B Bethlehem and Cambria rails, in Table 1. In the case of the Lehigh Valley, a possible explanation is that their discard was from 15 to 20 per cent.

The failures of 85-lb. P. S. Gary, Nos. 31 and 73, on the Pennsylvania Lines, have been traced in almost every instance to the former practice of protecting the ingot stools with scrap material, and it has been found since the practice was stopped, in 1909, that the number of failures has been greatly reduced. The experience with the Gary rail on the Union Pacific, the Southern Pacific, and the Rock Island Lines has been precisely the same.

In the case of Nos. 5, 7 and 12 on the Big Four, Northern Pacific and Union Pacific, respectively, breakages were the most predominant kinds of failures, being 90-lb. A.S.C.E. Carnegie rail, 85-lb. A.S.C.E. Carnegie rail and 80-lb. A.S.C.E. Lackawanna rail, and the question naturally arises: Is it due to the high specified carbon .50 to .60? Breakages are also predominant in 8 and 9, in the case of 75-lb. A.S.C.E. Illinois rail on the Chicago, Indianapolis & Louisville Railway and of 75-lb. B.&M. Lackawanna rail on the Boston & Maine, with much lower carbon specified. Furthermore, in the case of the St. Louis & San Francisco No. 87, 85-lb. A.S.C.E. Illinois rail and Union Pacific No. 84, 90-lb. C.S. Illinois rail, we have a low number of breakages with the same specified high carbon.

Central Railroad of New Jersey No. 22, 90-lb. A.S.C.E. Carnegie rail is very high in hardeners, C. .54 to .64 and Mn. 1.05 to 1.30, and has a pretty considerable number of failures, but not as many as in the case of others with lower hardeners, such as Chicago, Indianapolis & Louisville No. 8, 75-lb. A.S.C.E. Illinois, C. .40 to .50 and Mn. .75 to 1.05.

However, where breakages are predominant, they are found to be in most cases of the higher specifications for carbon, .48 to .58 and .50 to .60 in the case of Bessemer rail, while it is not so pronounced in the case of Open-Hearth. It may possibly be considered, therefore, that those are a little beyond the limits for P. .10.

It is difficult to understand why breakages are prevalent in the case of Central Railroad of New Jersey No. 14, 90-lb. A.S.C.E. Bethlehem Open-Hearth, with C. .57 and P. .031, unless it is the difficulty usually experienced by a mill when just beginning a new process of manufacture.

On page 71 is a condensed summary for all rail, which shows very clearly the superiority of Open-Hearth over Bessemer steel. The average number of failures per 10,000 tons of new rail laid for Open-Hearth is

TABLE 3.

Weight of Rail per Yard	Figures below are Percentages of Total Failures								Year
	Broken		Head Failures		Web Failures		Base Failures		
	Bess.	O.-H.	Bess.	O.-H.	Bess.	O.-H.	Bess.	O.-H.	
100	20 34	19 23½	58 47½	40¾ 56½	14½ 9	28¼ 12	7½ 9½	12 8	1909 1910
95	14		81½		2½		2		1910
90	17 24	34 38	74 58	50¾ 46½	6 9	12 10½	3 9	3¼ 5	1909 1910
85	16 30	21¼ 21	69¾ 53	63¾ 63	6¼ 5	9 11	8 12	6 5	1909 1910
80	15¾ 23	15 34	73 67	60 44	6¼ 6½	19 12	5 3½	6 10	1909 1910
78	79		21						1910
75	28 32	35¼	51½ 49	30¼	17½ 12	13¼	7	21¼	1909 1910
72	54		38½		7		0½		1910

TABLE 4—ORDER OF SUPERIORITY OF DIFFERENT RAIL SECTIONS ACCORDING TO WEIGHT OF RAIL AND MATERIAL, BASED ON RELATIVE NUMBER OF RAIL FAILURES PER 10,000 TONS OF NEW RAIL LAID.

	100		90		85		80		75	
	Bess.	O.-H.	Bess.	O.-H.	Bess.	O.-H.	Bess.	O.-H.	Bess.	O.-H.
1	N. Y. N. H. & H.	A. R. A.-B.	A. R. A.-A.	S. F.	Mo. P.	A. S. C. E.	A. R. A.-A.		Mo. P.	C. S.
2	A. R. A.-B.	A. R. A.-A.	G. N.	G. N.	P. R. R.	P. S.	Dudley		P. R. R.	Lacka.
3	P. S.	P. & R.	D. L. & W.	A. R. A.-A.	P. S.	A. R. A.-A.	A. S. C. E.		B. & M.	A. S. C. E.
4	P. R. R.	A. S. C. E.	A. S. C. E.	A. R. A.-B.	A. S. C. E.	Mo. P.	Camb.		A. S. C. E.	
5	A. R. A.-A.	Dudley.	C. S.	C. S.	Q.	Q.			C. S.	
6	P. & R.	P. S.	A. R. A.-B.	D. L. & W.	A. R. A.-A.					
7	A. S. C. E.	N. Y. N. H. & H.		A. S. C. E.						
8	Dudley	P. R. R.								

11½, as against 33 for Bessemer. In this table the alloys do not show to very good advantage, but upon examination in detail it will be found that the poor results are due to special cases.

Examining the details of this same table, the kinds of failures are classified as follows, and a comparison with the six months ending October 31, 1909, is given, taken from the previous report:

	One Year Ending Oct. 31, 1910.	Six Months Ending Oct. 31, 1909.
"Broken"	29¼%	19%
Head failures	55¼%	66½%
Web failures	7%	8½%
Base failures	8½%	6%

The above are subdivided as follows in Table 3 for the different weights of rail and between Bessemer and Open-Hearth steel, the comparison being also given for the 1909 period:

Breakages form a larger percentage than before and are largest for 100-lb. Bessemer, except in the case of 72-lb. and 78-lb. This may be due to a difference in classification, as the head failures are fewer. The web failures have rather diminished, while the base failures have increased in some cases and diminished in others. As to which failures predominate, as between Bessemer and Open-Hearth, there is not much difference.

If, from pages 64 to 70, we endeavor to determine the superiority of different rail sections by the relative number of failures per 10,000 tons or new rail laid, we arrive at the results given in Table 4.

If N.Y.N.H.&H. 100-lb. section stands first when made of Bessemer steel, why does the same section stand seventh when made of Open-Hearth, and so on? The reason is, of course, that the section of rail does not control the quality of material, although it should have some effect on it, because some sections of material are better rolling sections than others, and undoubtedly some sections are stronger than others when the quality of the material is the same. At the present time, however, the quality of the material is so variable that neither minor differences in sections nor in chemical composition have serious weight. Ultimately, however, when the art of rail-making becomes more refined, they ought to have weight, and, consequently, in the meantime, should not be entirely lost sight of. These points will be further brought out in the study of the diagrams which follow:

DIAGRAM I—COMPARISON BETWEEN DIFFERENT WEIGHTS OF RAIL, BESSEMER STEEL.

The information for this diagram is tabulated on pages 72 to 74. As in former reports, the head failures are the most numerous and those for the 90-lb. rail again lead. Those for 95-lb., 85-lb. and 80-lb. come next and are about the same in number, while the 100-lb. and 75-lb. are closely the same.

The number of breakages are a little more numerous for 85-lb. than for 75-lb., while the web and base failures are quite insignificant.

DIAGRAM 2—COMPARISON BETWEEN DIFFERENT WEIGHTS OF RAIL, OPEN-HEARTH STEEL.

The information for this diagram is tabulated on pp. 75 and 76.

The superiority of Open-Hearth over Bessemer steel is again emphasized in this diagram as compared with No. 1. The breakages and head failures for the 80-lb. predominate and are quite few for all the others.

DIAGRAM 3—COMPARISON BETWEEN DIFFERENT SECTIONS OF RAIL, BESSEMER STEEL.

The information for the construction of the diagram is tabulated on pp. 77 to 81.

Diagram 1 showed that the greatest number of head failures occurred in the case of 90-lb. rail. This diagram shows that they are most numerous in the case of A.R.A.-B, C.S. and A.S.C.E. sections.

The A.R.A.-B is on the Baltimore & Ohio and is No. 1 in Table 2, and there is nothing peculiar about the specified chemical composition. The C.S. is Nos. 27, 33 and 42 of Table 2 on the Oregon Short Line, Union Pacific and Illinois Central, respectively, and the specified chemical composition is somewhat different from the general run, having C. .50 to .60 for the first two, and .55 to .65 in the last, with, however, lower P., viz., .085.

The next largest number of head failures occurred in the case of A.R.A.-A 85-lb., then C.B.&Q. 85-lb. and Cambria 80-lb. The first is No. 35 of Table 2 and is Bessemer rail of the Illinois Steel Company on the Atchison, Topeka & Santa Fe. It is a section designed by that company in accordance with the principles laid down by the American Railway Association, as that Association did not make any specific design for 85-lb. rail. The specified chemical contents are in accordance with the usual practice, and the reason for the numerous head failures and breakages is not apparent. The C.B.&Q. 85-lb. is No. 4 of Table 2 and has higher carbon than is usual, .48 to .58.

With reference to breakages, the largest number in diminishing order are in the case of A.R.A.-A 85-lb. (35), D.L.&W. 90-lb., C.S. 90-lb. (27, 33 and 42), Cambria 540, Dudley 100-lb. (85) and A.S.C.E. 90-lb. The A.R.A.-A 85-lb. on the Santa Fe and the C.S. 90 have already been spoken of above. The D.L.&W. rail is shown on page 15, but the chemical composition is not given. It is a 1908 lot of 4,192 tons of Lackawanna rail. The Dudley 100-lb. was somewhat high in phosphorus.

It is noticeable that all failures of A.R.A.-B 90-lb. rail are more numerous than A.R.A.-A 90-lb., but the reverse is the case with the 100-lb. section.

The web failures of the P.&R. 100-lb. are rather noticeable. This is Maryland 1910 rail of the following composition:

C	.55 to .65
P	.07
Mn	.90 to 1.00
Si	.20

It is thought they were due to sponginess, and the presence of slag in "A" rails.

In Table No. 5 is given a statement of number of head failures per 10,000 tons of new rail laid, in diminishing order, with the object of trying to discover whether the different sections of rail have any influence on the number of head failures, i. e., whether a thin or heavy head is the better, or whether a stiff or low section is the better. Opposite to each a letter has been set, indicating whether the section has a heavy or thin head and whether it is of stiff or low design, using the A.R.A.-A as standard for thin head and stiff design and A.R.A.-B as standard for heavy head and low design; except in the case of 85-lb. C.P.R. is used as standard for thin head, the Dudley for the stiff design, and the P.S. for heavy head and low design.

TABLE 5—STATEMENT OF HEAD FAILURES PER 10,000 TONS OF RAIL LAID IN DIMINISHING ORDER

Section	Weight	Tangent or Curve	Number of Head Failures per 10,000 Tons	Heavy or Thin Head	Stiff or Low Design
A. R. A.-B	90	C	60.8	H	L
A. R. A.-A	85	T	40.7	T	S
Cam. 540	80	T	27	....	....
A. R. A.-A	85	C	25.5	T	S
C. B. & Q	85	T	22.9	T	L
C. S	90	T	22.7	T	S
C. S	90	C	20.1	T	S
A. S. C. E	90	T	18.3	H	L
P. & R	100	C	16.9	H	L
C. B. & Q	85	C	16.4	T	L
B. & A	95	C	15.3	T	L
C. S	75	T	14.7	T	S
A. R. A.-A	100	T	14.3	T	S
A. S. C. E	100	T	13.8	H	S
A. S. C. E	80	T	13.8	H	L
A. S. C. E	90	C	13.1	H	L
P. S	85	C	11.8	H	L
A. R. A.-A	100	C	11.6	T	S
B. & A	95	T	11.1	T	L
A. S. C. E	85	T	11.1	T	S
A. R. A.-A	90	T	10.8	T	S
Dudley	100	C	10.7	T	S
C. S	75	C	10.6	T	S
Dudley	100	T	9.2	T	S
P. S	100	C	9.1	H	L
G. N	90	C	8.4	T	L

Of the 100-lb., the N.Y.N.H.&H. 100-lb. section makes the best showing, and can be classed as stiff section with heavy head.

The next best is the A.R.A.-B of heavy head and low design, and then the P.S. of heavy head and low design, while last year the A.R.A.-A of thin head and stiff design preceded.

Of the 90-lb. the first is the A.R.A.-A of thin head and stiff design and then the Great Northern of thin head and low design, while last year the Great Northern came first.

Of the 85-lb. the Mo. Pac. comes first and then the P.R.R. and P.S., both of heavy head and low design.

Of the 80-lb. the best showing is made by the A.R.A.-A of thin head and stiff design and then the Dudley of heavy head and stiff design.

DIAGRAM 4—COMPARISON BETWEEN DIFFERENT SECTIONS OF RAIL, OPEN-HEARTH STEEL.

The information for the diagram is tabulated on pp. 82 to 84.

It presents a very different appearance from Diagram No. 3 and again shows the superiority of Open-Hearth over Bessemer rail. We are reminded, however, by some irregularities that Open-Hearth steel is not perfect and there are defects of manufacture or material to be overcome in its case, as well as in the case of the Bessemer.

The greatest number of head failures is of P.R.R. 100-lb., the next C.B.&Q. 85-lb., the next Mo.Pac. 85-lb. and then A.S.C.E. 90-lb., the two latter being about equal.

In order to determine the effect, if any, of chemical composition, the percentages of ingredients are given below:

P. R. R. 100 Pa. Steel 1905	C. B. & Q. 85 Beth. 1908	Mo. P. 85 C. F. & I. 1910	A. S. C. E. 90 Bethlehem 1907–1909	
			C. R. R. of N. J.	L. V. R. R
C. .85	.55 to .67	.63	.57	.70 to .80
P. .012	.04	.06	.031	.04
Mn .65	.70 to 1.00	.85	.82	.80 to 1.05
Si. .041		.20		

The P.R.R. rail was but a small experimental lot, made by the Pennsylvania Steel Company in 1905, and may have been too hard with the high carbon, although the phosphorus is very low. On the other hand, the C.B.&Q. and the C.R.R. of N.J. rail may have been too soft. The Mo. Pac. rail was reported by the Denver & Rio Grande, no reports at all having been received from the Missouri Pacific.

There is nothing else unusual in connection with the diagram, except the number of breakages of A.S.C.E. 90-lb., the composition of which has already been given above. The best showing has been made by the A.R.A.-B 100-lb., A.R.A.-A 100-lb., C.S. 75-lb., S.Fe 90-lb. and P.&R. 100-lb.

The A.R.A.-B is Bethlehem, Cambria and Maryland 1910 rail on the B. & O., Illinois Steel 1909 on the Chicago & Northwestern, Bethlehem 1910 rail on the Erie, and Algoma 1910 rail on the Michigan Central, the chemical composition of which conforms with the usual limits, except that a portion of it on the Baltimore & Ohio has pretty high carbon, .65 to .80, for .04 phosphorus.

The A.R.A.-A is Maryland, Bethlehem and Pennsylvania 1910 rail, on the Central Railroad of New Jersey, and Gary 1910 rail on the Rock Island. The chemical composition differs in each case and is as follows:

	Pennsylvania	Maryland	Bethlehem	Gary
C.	.70 to .85	.62 to .75	.70 to .83	.63 to .76
P.	.04	.04	.04	.04
Mn.	.60 to .90	.60 to .90	.60 to .90	.60 to .90
Si.	.20	.20	.20	.10 to .20

It will be noted that, in some of these cases, the carbons are even higher than above, and the phosphorus lower.

The C.S. 75-lb. is Bethlehem 1909 and C.F.&I. 1907-1910 rail on the Oregon Railroad & Navigation Company, and Maryland 1906 on the Arizona & Eastern. The O.R.R.&N.Co. rails ought to be very soft with C. .45 for P. .025. The Maryland rail ought to have been classed as Bessemer with .085 phosphorus.

The Santa Fe 90-lb. is Illinois 1909 and 1910 steel, with C. .59 to .72, P. .04, Mn. .60 to .90 and Si. .20.

The P.&R. 100-lb. is Pennsylvania 1909 and 1910 steel with C. .70 to .85, P. .03, Mn. .60 to .90 and Si. .20.

Last year there were no head failures of N.Y.N.H.&H. 100-lb., but this year there are some breakages of 10,741 tons of Bethlehem 1908 and 1910 rail with C. .70 to .77, P. .02 to .035, Mn. .70 to 1.00 and Si. .10 to .21.

In addition to the above there is but one failure of 9,825 tons of Pennsylvania steel for 1908 to 1910, with C. .71 to .90, P. .009 to .028, Mn. .60 to .90, Si. .05 to .13 and S. .02 to .079. It is to be noted that there are a few base failures with this section, and reference to Vol. 12, Part 2, page 149, will show that it has a thin base.

It was also mentioned last year that there were very few failures of the D.L.&W. 90-lb., while this year there are some breaks. It is Bethlehem 1908-1910 rail, with C. .67 to .80, P. .04, Mn. .75 to 1.05, Si. .20 and S. .05.

Last year there were no failures of the Dudley 100-lb., but this year there are a few, principally head failures. There are but a few tons, 4,404, divided between Lackawanna and Bethlehem, in 1908 and 1909.

DIAGRAM 5—COMPARISON OF FAILURES FOR DIFFERENT PERIODS OF LIFE.

The information for the diagram is tabulated on pp. 85 and 86.

There are comparatively few failures during the first year, the principal exception being P.R.R. 100-lb.

The most failures occurred from the first to the sixth year.

FAILURES WITH RESPECT TO THE POSITION IN THE INGOT, PP. 87 TO 141.

The marking of the rails to distinguish the position in the ingot has become very general, and the reports were much more complete than ever before.

For convenient reference, Table No. 6 has been made from the reports. The failures of "A" rails are the most numerous, but there are also very many failures of "B" and "C" rails and no inconsiderable number of "D" and "E", while there are occasional ones even lower down.

Unless there is an improvement in the making of the ingots, it will require the elimination entirely of the "A", "B" and "C" rails to be sure of having only sound ones in the track. As this would mean a great waste of material, with resultant loss of economy, it emphasizes the necessity for continued study of rail manufacture in order to obtain rails as nearly faultless as possible, without extravagance.

TABLE 6—SUMMARY OF NUMBER OF RAIL FAILURES ACCORDING TO THE POSITION IN THE INGOT.

(Top of Ingot is denoted by "A" and lower positions by succeeding letters)

Railroad	Weight per Yd.	Section	Kind of Steel	Manufacturer	Position in Ingot								Total
					A	B	C	D	E	F		Unknown	
B. & O.	100	A. R. A.-A.	Bessemer	Carnegie	.....	5	6	.....	.....	.....	.....	.....	11
C. B. & Q.	100	A. R. A.-A.	Bessemer	Colo. Fuel & Iron	2	1	1	1	.....	.....	.....	3	8
Pa. Lines—N. W. S.	100	A. R. A.-A.	Bessemer	Carnegie	.....	5	.....	.....	.....	.....	.....	.....	5
Pa. Lines—S. W. S.	100	A. R. A.-A.	Bessemer	Carnegie	.....	14	.....	.....	.....	.....	.....	4	18
B. & O.	100	A. R. A.-B.	Bessemer	Maryland	31	4	4	4	2	.....	.....	1	46
B. & L. E.	100	A. R. A.-B.	Bessemer	Carnegie	9	13	2	1	.....	.....	.....	2	27
B. & O.	100	A. S. C. E.	Bessemer	Maryland	27	8	5	4	3	2	.....	93	142
B. & O.	100	A. S. C. E.	Bessemer	Cambria	8	2	1	1	.....	1	.....	100	113
C. B. & Q.	100	A. S. C. E.	Bessemer	Illinois	16	6	4	.....	.....	.....	(G) 4	17	47
N. Y. C. & H. R.	100	Dudley	Bessemer	Lackawanna	102	91	51	26	5	.....	.....	386	661
Cumb. Valley	100	P. R. R.	Bessemer	Maryland	6	4	2	1	2	3	.....	2	20
Penna. R. R.	100	P. S.	Bessemer	Cambria	20	6	5	6	7	1	.....	4	49
Penna. R. R.	100	P. S.	Bessemer	Maryland	.....	2	.....	2	1	.....	.....	.....	5
Pa. Lines—N. W. S.	100	P. S.	Bessemer	Carnegie	1	9	2	.....	.....	.....	.....	4	16
Pa. Lines—N. W. S.	100	P. S.	Bessemer	Illinois	5	1	.....	.....	.....	.....	.....	.....	6
Pa. Lines—S. W. S.	100	P. S.	Bessemer	Carnegie	.....	27	1	.....	.....	.....	.....	2	30
Pa. Lines—S. W. S.	100	P. S.	Bessemer	Cambria	4	2	1	.....	2	.....	.....	.....	9
P. & R.	100	P. & R.	Bessemer	Maryland	5	4	6	1	4	.....	.....	.....	20
P. & R.	100	P. & R.	Bessemer	Carnegie	9	.....	.....	.....	.....	.....	.....	.....	9
B. & O.	90	A. R. A.-A.	Bessemer	Illinois	19	.....	5	.....	.....	.....	.....	4	28
B. & O.	90	A. R. A.-A.	Bessemer	Carnegie	28	1	24	.....	1	.....	.....	13	67
O. S. L.	90	A. R. A.-A.	Bessemer	Colo. Fuel & Iron	.....	1	1	2	.....	.....	.....	.....	4
Sou. Pac.	90	A. R. A.-A.	Bessemer	Illinois	2	5	1	.....	.....	.....	.....	.....	8
B. & O.	90	A. R. A.-B.	Bessemer	Carnegie	409	83	363	45	4	4	.....	42	950
B. & O.	90	A. R. A.-B.	Bessemer	Maryland	40	6	.....	1	1	.....	.....	1	49
B. & O.	90	A. R. A.-B.	Bessemer	Cambria	23	11	1	8	2	2	.....	5	52
Nor. Pac.	90	A. R. A.-B.	Bessemer	Carnegie	5	2	10	.....	.....	.....	.....	25	42
Nor. Pac.	90	A. R. A.-B.	Bessemer	Lackawanna	2	1	1	2	.....	.....	.....	7	13
C. R. R. of N. J.	90	A. S. C. E.	Bessemer	Maryland	32	13	31	42	49	2	.....	52	221
C. R. R. of N. J.	90	A. S. C. E.	Bessemer	Lackawanna	21	8	4	3	.....	.....	.....	69	105
L. V.	90	A. S. C. E.	Bessemer	Maryland	.....	2	.....	15	48	2	.....	41	108
P. & R.	90	A. S. C. E.	Bessemer	Maryland	119	48	38	30	9	.....	.....	44	288
D. L. & W.	90	D. L. & W.	Bessemer	Lackawanna	2	5	5	5	.....	.....	.....	1	18
Gt. Nor.	90	G. N.	Bessemer	Cambria	8	1	1	9	4	1	.....	26	50
Gt. Nor.	90	G. N.	Bessemer	Illinois	4	.....	6	.....	.....	2	.....	18	30
Gt. Nor.	90	G. N.	Bessemer	Maryland	11	3	.....	.....	.....	.....	.....	.....	14
B. & O.	85	A. S. C. E.	Bessemer	Carnegie	84	31	52	12	5	5	.....	856	1045
B. & O.	85	A. S. C. E.	Bessemer	Maryland	59	4	6	3	16	4	.....	57	149
B. & O.	85	A. S. C. E.	Bessemer	Cambria	3	5	1	1	6	.....	.....	132	148
N. & W.	85	A. S. C. E.	Bessemer	Carnegie	17	2	5	.....	.....	.....	.....	106	130
N. & W.	85	A. S. C. E.	Bessemer	Maryland	12	1	.....	1	.....	1	.....	33	48
Nor. Pac.	85	A. S. C. E.	Bessemer	Illinois	47	12	46	20	1	2	.....	2128	2256
Nor. Pac.	85	A. S. C. E.	Bessemer	Lackawanna	43	26	22	26	2	2	.....	374	495
C. R. I. & P.	85	A. S. C. E.	Bessemer	Illinois	12	9	17	3	1	.....	.....	1	43
C. A. & C.	85	P. S.	Bessemer	Carnegie	80	8	88	6	.....	.....	.....	2	184

TABLE 6—SUMMARY OF NUMBER OF RAIL FAILURES ACCORDING TO THE POSITION IN THE INGOT—CONTINUED.

(Top of Ingot is denoted by "A" and lower positions by succeeding letters)

Railroad	Weight per Yd.	Section	Kind of Steel	Manufacturer	Position in Ingot								Total
					A	B	C	D	E	F		Unknown	
P. R. R.	85	P. S.	Bessemer	Cambria	6	1	1	2	2	1		4	17
P. R. R.	85	P. S.	Bessemer	Maryland	2		2	1	1				6
Pa. Lines—N. W. S.	85	P. S.	Bessemer	Carnegie	37	5	39	9				8	98
Pa. Lines—S. W. S.	85	P. S.	Bessemer	Carnegie	42	15	43	5	1	5		4	115
Pa. Lines—S. W. S.	85	P. S.	Bessemer	Illinois	11	1	4	1				1	18
C. B. & Q.	85	C. B. & Q.	Bessemer	Illinois	248	44	37	32	3	5	(G) 12	734	1115
C. B. & Q.	85	C. B. & Q.	Bessemer	Colo. Fuel & Iron	4	6	3	4	6		(H) 4	185	212
N. Y. C. & H. R.	80	Dudley	Bessemer	Lackawanna	13	18	6	11	1			114	163
P. R. R.	100	P. S.	O.-H.	Carnegie	3	1				2			6
P. R. R.	100	P. S.	O.-H.	Cambria	3	2	1	4	3	1			14
P. R. R.	100	P. S.	O.-H.	Maryland				1				1	2
P. R. R.	100	P. S.	O.-H.	Bethlehem		2	1	6	7				16
P. R. R.	100	P. S.	O.-H.	Lackawanna	16	2	3						21
P. R. R.	100	P. S.	O.-H.	Pennsylvania	3	1	2	4	1			2	13
Pa. Lines—N. W. S.	100	P. S.	O.-H.	Illinois, Gary	1	2		5	2	2	(H) 1	5	18
P. & R.	100	P. & R.	O.-H.	Pennsylvania		2	1	3	1				7
C. R. R. of N. J.	90	A. R. A.-A.	O.-H.	Bethlehem	17	9	15	15	10	3		26	95
C. B. & Q.	90	A. R. A.-A.	O.-H.	Illinois, Gary	19	9	14	7	8	9	(G) 31	51	148
Sou. Pac.	90	A. R. A.-A.	O.-H.	Illinois, Gary	1	2		1	1			11	16
B. & O.	90	A. R. A.-B.	O.-H.	Bethlehem	63	27	28	17	24	16		46	221
Nor. Pac.	90	A. R. A.-B.	O.-H.	Illinois, Gary	7	4	11	1	5	4		30	62
L. V.	90	A. S. C. E.	O.-H.	Bethlehem	42	32	26	32	30	2		174	338
D. L. & W.	90	D. L. & W.	O.-H.	Bethlehem	2	12	7	6	20	1		29	77
Gt. Nor.	90	G. N.	O.-H.	Bethlehem	4	6	2	3	7	3	(H) 8	10	43
Gt. Nor.	90	G. N.	O.-H.	Illinois, Gary	2	4	2	3			(G) 1 (J) 1	3	16
N. & W.	85	A. S. C. E.	O.-H.	Cambria	3	1	1	3	1	1		27	37
N. & W.	85	A. S. C. E.	O.-H.	Pennsylvania	2	1		3	1			3	10
N. & W.	85	A. S. C. E.	O.-H.	Bethlehem	2	4		3	1	5			15
C. R. I. & P.	85	A. S. C. E.	O.-H.	Illinois, Gary	1	2			1		(G) 1	1	6
P. R. R.	85	P. S.	O.-H.	Carnegie		1		1					2
P. R. R.	85	P. S.	O.-H.	Cambria	1	1	1		4	2		1	10
Pa. Lines—S. W. S.	85	P. S.	O.-H.	Illinois, Gary	3	5	4	1		4	(G) 2	14	33
C. B. & Q.	85	C. B. & Q.	O.-H.	Bethlehem	5	2	1	3	3			16	30
B. & A.	100	Dudley	Ferro Titanium	Lackawanna	73	37	25	1				48	184
C. R. R. of N. J.	90	A. S. C. E.	Ferro Titanium	Lackawanna	8	4	10	15				1	38
C. R. R. of N. J.	90	A. R. A.-A.	Nickel Chromium	Bethlehem	97	76	149	88	96	2		58	566

COMPARATIVE WEAR OF SPECIAL AND ALLOY RAIL, PP. 142 TO 162.

Several of the companies are making trials of experimental lots of both Special Bessemer and Open-Hearth steel, and with different alloys, such as ferro-titanium, nickel, chromium-nickel, etc., but in some instances the results have not been very satisfactory. The failures are given in detail on pp. 61, 62, 63, 67 and 68, and the record of wear on pp. 142 to 162. The average number of failures per 10,000 tons of rail laid for the different kinds tested are as follows:

Open-Hearth Steel, with ferro-titanium	12
Bessemer Steel, with ferro-titanium	13½
Bessemer Steel, with nickel	96
Open-Hearth Steel, with chromium-nickel	640

Ferro-Titanium Treatment:

The record for failures is bad on the Central Railroad of New Jersey, being 1,019 per 10,000 tons of rail, but the quantity tested is very small—373 tons. This is 90-lb. A.S.C.E. section, rolled by the Lackawanna Steel Company in 1909, with C. .45 to .55, P. .10, Mn. .84 to .114, Si. .20 and F.T. .3. Other lots of the rail have made a better showing. The failures are thought to be due to imperfect rolling and not to the ferro-titanium.

The comparative wear tests were made on the Baltimore & Ohio, Lake Shore & Michigan Southern and New York Central Lines.

The following tests are being made on the Baltimore & Ohio:

90-lb. A.R.A.-B Maryland Bessemer rail with ferro-titanium is being compared with Maryland Open-Hearth rail on Kessler's Curve. The per cent. of area of head abraded was 3.8 and 4.4 for ferro-titanium and 4.2 for Open-Hearth in four months.

Also 100-lb. A.S.C.E. Maryland Bessemer steel with ferro-titanium was compared with Maryland Bessemer steel on the same curve, and in one year ten months the per cent. of area of head abraded was 9.5 for ferro-titanium and 17.7 for Bessemer. This Bessemer rail was worn out and replaced by Cambria Bessemer, which wore 6.4 per cent. in less than six months.

On the Lake Shore & Michigan Southern, 100-lb. A.S.C.E. Lackawanna steel with ferro-titanium is being compared with ordinary Bessemer rail. In some of these tests not much superiority is shown for the ferro-titanium, while in others there is considerable.

On the New York Central & Hudson River Railroad, 80-lb. Dudley Lackawanna steel with metallic titanium .033 is being compared with 80-lb. Dudley ordinary Bessemer, the record for one year and six months showing less wear for the ordinary Bessemer than for the ferro-titanium, although the difference is but slight.

It will thus be observed that up to the present time the results are conflicting, the one good test on the Baltimore & Ohio perhaps being due to the higher carbon, while the other tests, where the results are about the same, are with the usual carbon for that quality of steel.

The large number of failures on the Central Railroad of New Jersey, mostly broken base, is rather alarming and discouraging.

Steel with Chromium-Nickel:

The record for 90-lb. A.S.C.E. Open-Hearth rail with chromium and nickel on the Central Railroad of New Jersey has been very bad so far as failures are concerned, there having been 1,129 per 10,000 tons of rail laid, mostly breakages. It is Bethlehem steel, 1909 manufacture, but the chemical composition is unknown.

Small lots have also been tested on the B. & O. and the Erie, with a large number of failures. That on the B. & O. is 90-lb. A.R.A.-B Bethlehem rail, 1909 and 1910, with 595 failures per 10,000 tons, and that on the Erie, 90-lb. A.S.C.E. Bethlehem 1909 rail with 289 failures per 10,000 tons, both on page 63. The amount of nickel is 2 per cent. to 2½ per cent., and the chromium .5 per cent. to .9 per cent. In the case of the B. & O. the carbon is rather low for Open-Hearth steel, while on the Erie it is more nearly the usual amount.

A small lot on the New York, Ontario & Western has given better results, and also a larger amount on the Lehigh Valley, although the number of failures, especially breakages, is very considerable.

Comparative tests for wear are being conducted by the Baltimore & Ohio and the Lehigh Valley Railroad.

The Baltimore & Ohio is comparing 90-lb. A.R.A.-B Bethlehem steel, containing nickel and chromium, with ordinary Bethlehem Open-Hearth rail on different curves, ranging in degree from 4 deg. 30 min. to 9 deg. 30 min.

The results are variable, in one case the chrome-nickel showing a greater percentage of wear than the Open-Hearth, while in other cases the Open-Hearth shows 50 per cent. greater wear than chrome-nickel, the duration of time being one and one-half years. It is difficult to understand the difference, as the respective kinds of material are the same in each case.

When compared with ordinary Cambria Bessemer rail, the per cent. of area of head abraded was from 2½ to 3 times as much for the Bessemer rail as for the chromium-nickel rail.

In the Lehigh Valley tests, 90-lb. A.S.C.E. Bethlehem steel, with nickel and chromium, was compared with ordinary Open-Hearth rail and the per cent. of area of head abraded in from 8 to 18 months was 70 per cent. greater in the case of the Open-Hearth than of the chrome-nickel.

Rail of Mayari Ore:

A test is being conducted by the Pennsylvania Lines of 85-lb. P. S. Pennsylvania Steel Company's Open-Hearth rail of Mayari ore from Cuba, and in ten months ordinary Maryland Bessemer steel shows twice the wear. The chemical composition is: C. .805, P. .022, Mn. .87, Si. .17, S. .035, Nickel .97 and Chromium .21. It will be noted that it is a chromium-nickel rail, but of very different composition from the tests cited above.

Manganese Steel:

The Norfolk & Western is comparing 85-lb. A.S.C.E. manganese steel with ordinary Carnegie Bessemer, and up to the present time the per cent. of area of head abraded is a trifle over three times as much for the Bessemer as for the manganese. The composition of the manganese rail is: C. .77, P. .06, Mn. 9.93, Si. .25, S. .038, and the test has lasted for nineteen months.

On the Lake Shore & Michigan Southern, 85-lb. P. R. R. manganese rail of the Pennsylvania Steel Company is being compared with ferro-titanium steel, and in eight months the ferro-titanium shows a little more than twice as much wear as the manganese.

Miscellaneous:

The Baltimore & Ohio made a comparative test between 90-lb. A.R.A.-A Illinois steel and 90-lb. A.R.A.-B Carnegie steel on a 7 deg. curve. In two years the per cent. of area of head abraded was 23.4 for the "A" and 13.4 for the "B".

The Baltimore & Ohio compared the wear of 90-lb. A.R.A.-B Bethlehem Open-Hearth rail with Cambria Bessemer on a 7 deg. 5 min. curve, and in one year the per cent. of area of head abraded was 9.8 for the Open-Hearth and 26.9 for the Bessemer.

The Lake Shore & Michigan Southern compared 80-lb. A.S.C.E. rail made by the electric process of the Illinois Steel Company with ordinary Bessemer rail, with the result that in eight months but little difference between them was shown.

The New York Central & Hudson River Railroad compared basic Open-Hearth rail of Bethlehem and Lackawanna manufacture, 100-lb. Dudley section, with ordinary Bessemer rail, same section, with but little difference in the comparative wear in a year and one-half.

THOUGHTS RESULTING FROM THE STUDY.

The most of the thoughts stated in Vol. 12, Part 2, page 28, may be repeated after this study, but some additional comments will be made:

(1) Study of these general statistics does not furnish accurate and specific information so as to determine the value of different sections of rail, because:

(a) The conditions of traffic are different.

(b) The conditions of roadbed are different.

(c) The conditions of ingot making and rolling practice are so different that the quality of the material varies widely, and, at the present time, this difference in quality of material eliminates differences in section; nevertheless, when the time comes that the difference in quality of material will be less, the influence of the section will be more apparent, for there is no doubt that one section is stiffer and stronger than another, according to the distribution of the material. Inasmuch as we are endeavoring to eliminate the differences in quality of material and bring it to a high state of perfection, we should not, in the meantime, lose sight of the desirable features of the rail section, but keep them constantly in mind, so that when we arrive at a good quality of metal we will also have a desirable rail section.

(2) A study of these general statistics tends to disclose unusual results, and were it not for their compilation, we would not have much information relative to the difference between Bessemer and Open-Hearth steel and concerning the various alloys.

(3) The general statistics are also important, in showing a relation between broken rails and failure of head, web and base.

(4) Their tabulation discloses the difference between Steel Companies when the sections and chemical composition are practically the same.

COMPARATIVE WEAR OF BESSEMER, OPEN-HEARTH AND NICKEL STEEL RAIL ON PENNSYLVANIA RAILROAD.

To the Members of the American Railway Engineering Association:

The Committee on Rail submits for your information the following statement and accompanying Exhibits "A" and "B," from Mr. Joseph T. Richards, Chief Engineer Maintenance of Way, Pennsylvania Railroad, in regard to comparative wear of Bessemer, Open-Hearth and Nickel Steel rail on the Pennsylvania Railroad.

June 22, 1911.

MR. CHAS. S. CHURCHILL,
Chairman, Committee on Rail, American Railway Engineering Association, Roanoke, Va.

Dear Sir:—From what I can gather from the progress reports of the work of the Committee to date, particularly the reports made to the Committee by Mr. Wickhorst, I am impressed that we are doing a great deal of work, but along the line which may be called experimental—we are to a degree hunting something new in the composition of rail, like "Chromium" and "Nickel."

If I am correct, I believe our Committee should turn its attention to perfecting the rail as we know it under the present well worked out analyses and specifications. If we fail in doing this, as railroad men I believe we are not doing our part, because a good rail can be made under our specifications and well-known composition, if the mill practice is right.

Experimenting outside of this line is "only beating around the bush," and working with a line ahead as long as a life line, and we will be continuing the long chase very much as we have been for the last generation, whereas, to get the rail we are seeking for requires prompt action in the direction above outlined.

I am firmly convinced that the mills can make a good rail. We all know very well what the mill practice did in making the old "John Brown" and "Charles Cammel" rail more than forty years ago at the crude mills and under the imperfect specifications of that time.

We have had Open-Hearth rails made by the mills and tested under heavy tonnage on our main line near Union Furnace, Middle Division, on a 6-deg. curve in the eastbound track, carrying both passenger and freight trains. The analyses of these rails are shown on the diagram presented. On this sheet is also marked the wear and life of the rail. (See diagrams marked Exhibit "A.")

It will be observed that the carbon was high and the phosphorus low. The comparison was: Open-Hearth, Carbon .79, Phosphorus .024, shown in red; Open-Hearth, Carbon .896, Phosphorus .009, shown in blue; Open-Hearth, Nickel, shown in green, and ordinary Bessemer, shown in black.

As we are developing the Open-Hearth rail I would call special attention to it in this test. It is shown in measurement No. 3 that the Bessemer rail was worn out and removed from track after service of 405 days, so that it is not shown in the following measurements, No. 4 to No. 8.

As to the Nickel Rail, High Carbon and Open-Hearth—the last measurement was taken after being in use 818 days. This High Carbon rail did not fail or break during the test, and was not nearly as much worn in 818 days as the Bessemer was in 405 days.

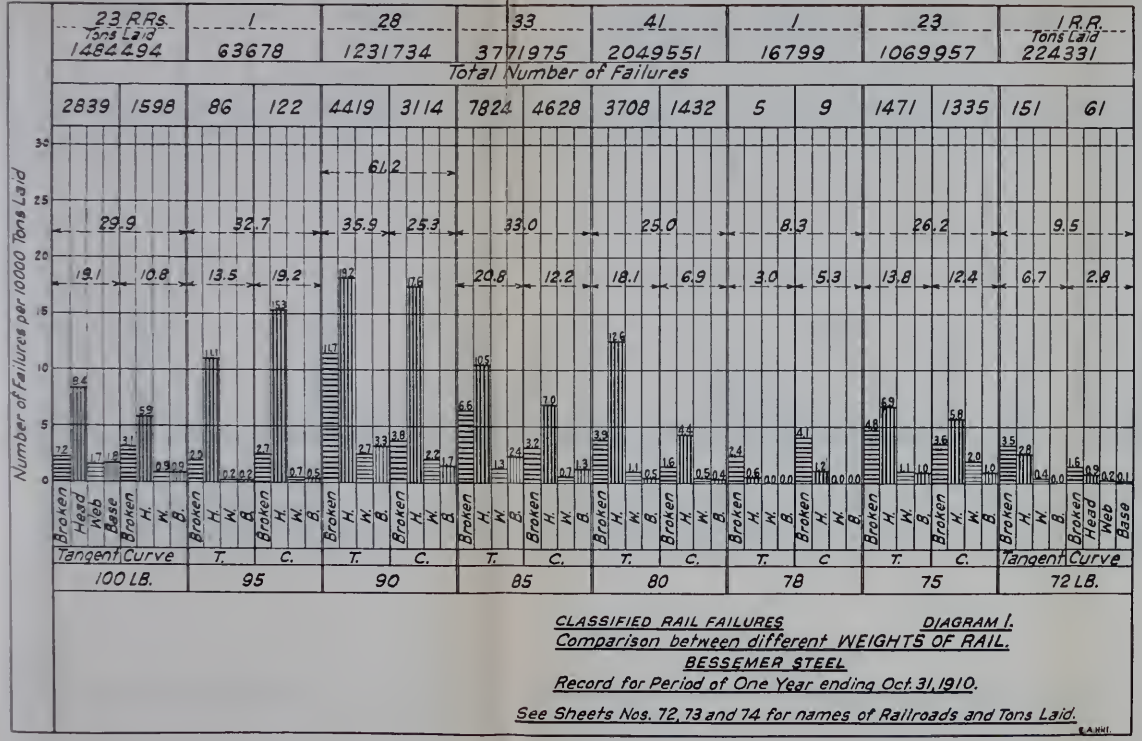
This shows the value and economy in using the High Carbon Open-Hearth rail, and we were so delighted that we thought great progress had been made. In asking the mills to reproduce this rail we have met with some success, although in some cases they have failed to give us rail that will come up to this test in durability; but it impresses me as a member of the Committee that we should work on the principle of the Economy Engineer, who emphasizes the importance of working on the "ratchet principle," i. e., holding on to what he has and adding to it, rather than allowing himself to slip back.

Of course, I am speaking of Open-Hearth rail; because the Bessemer process might well be eliminated, for the reason that, as we all know, ore suitable for Bessemer steel has practically disappeared, and the mills have largely been rebuilt for the Open-Hearth process. We are marking time when we pay too much attention to the Bessemer process.

In the long line that we are following in rail making I will give you another statement (see Exhibit "B") to show the results from Open-Hearth rails made under specifications in 1907 prepared jointly by the mill men and railroad men, and it is rather surprising to see this following about two years after our trial of 1905, in which an Open-Hearth rail was found to last so well and not break in track. I think the poor results shown in this statement are largely due to the fact that these rails have been too low in carbon and consequently too soft. It has turned out so badly that some of the railroads have reported to me that this rail is no better than Bessemer rail; yet it will be noted that the railroads have paid $31.00 to $35.00 per ton for this rail, when the ordinary rail was selling at $28.00 per ton.

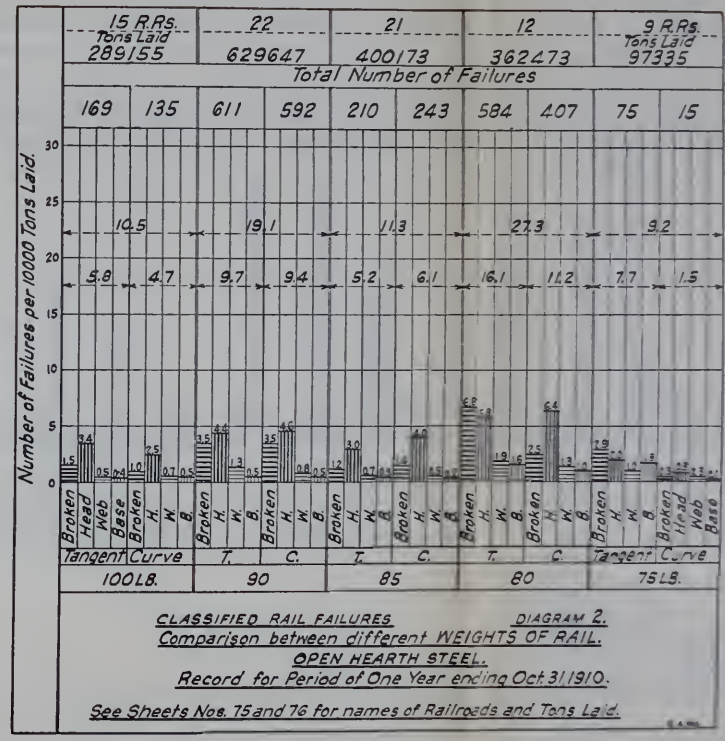
It is a well-known principle that as the phosphorus is decreased carbon should be increased. It can safely be done, and will give us a rail that will wear longer and not break.

As to the Titanium and Chrome-Nickel rail—i. e., experimenting with these new elements, I see no objection whatever—it is all proper in its way as a side issue; but it is slow, and should in no way hold back our perfecting the Open-Hearth rail, as we know it from mill practice and specifications.



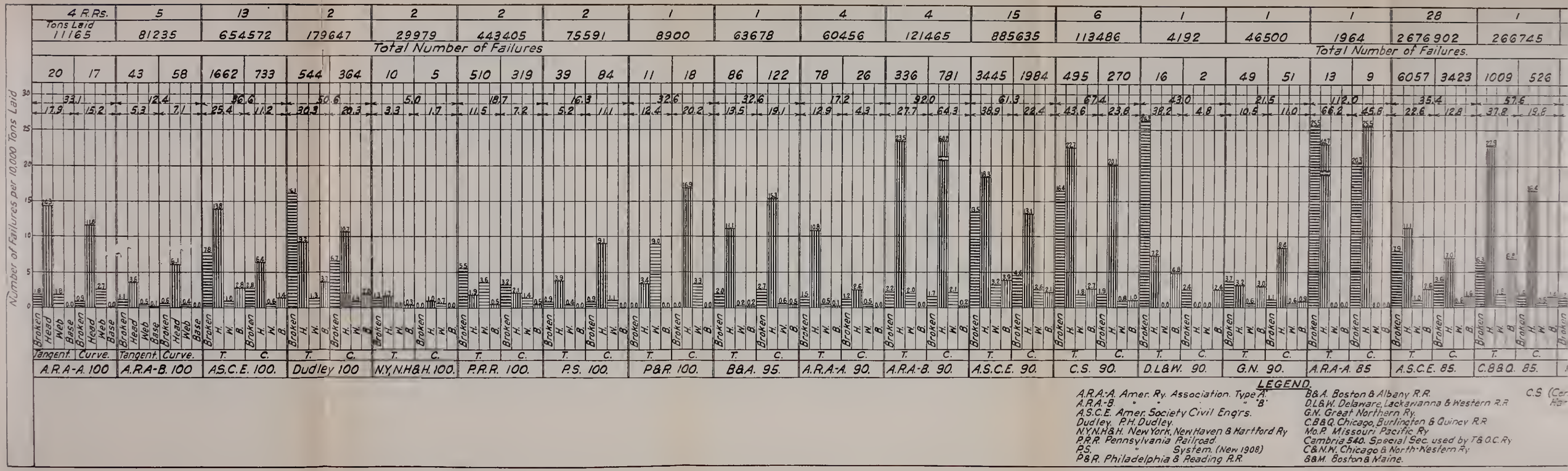
CLASSIFIED RAIL FAILURES DIAGRAM 1.
Comparison between different WEIGHTS OF RAIL.
BESSEMER STEEL
Record for Period of One Year ending Oct. 31, 1910.

See Sheets Nos. 72, 73 and 74 for names of Railroads and Tons Laid.



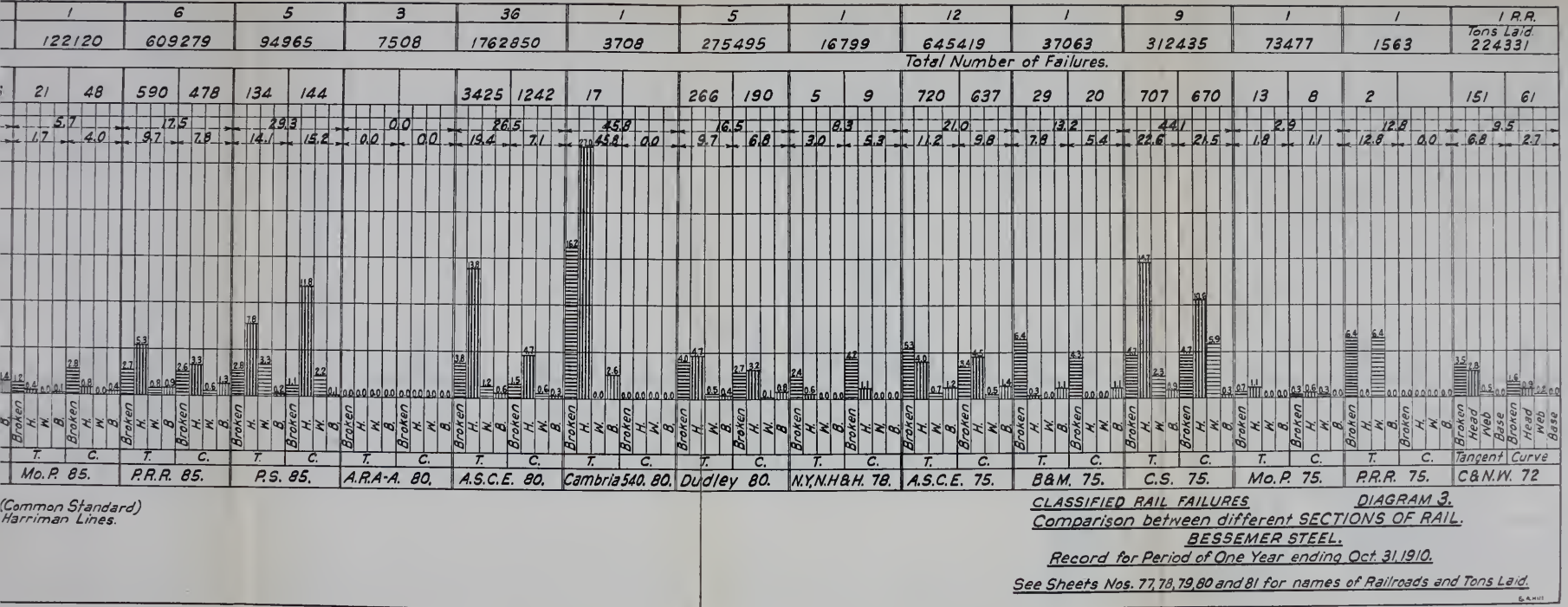
CLASSIFIED RAIL FAILURES DIAGRAM 2.
Comparison between different WEIGHTS OF RAIL.
OPEN HEARTH STEEL.
Record for Period of One Year ending Oct. 31, 1910.

See Sheets Nos. 75 and 76 for names of Railroads and Tons Laid.



LEGEND.

A.R.A-A. Amer. Ry. Association. Type "A"
A.R.A-B. " " " "B"
A.S.C.E. Amer. Society Civil Engrs.
Dudley. P.H. Dudley
N.Y.N.H&H. New York, New Haven & Hartford Ry
P.R.R. Pennsylvania Railroad
P.S. " System. (New 1908)
P&R. Philadelphia & Reading R.R.
B&A. Boston & Albany R.R.
D.L&W. Delaware, Lackarianna & Western R.R
G.N. Great Northern Ry.
C.B&Q. Chicago, Burlington & Quincy R.R
Mo.P. Missouri Pacific Ry.
Cambria 540. Special Sec. used by T&O.C.Ry
C&N.W. Chicago & North-Western Ry.
B&M. Boston & Maine.
C.S (Cer
Har



(Common Standard)
Harriman Lines.

CLASSIFIED RAIL FAILURES. DIAGRAM 3.

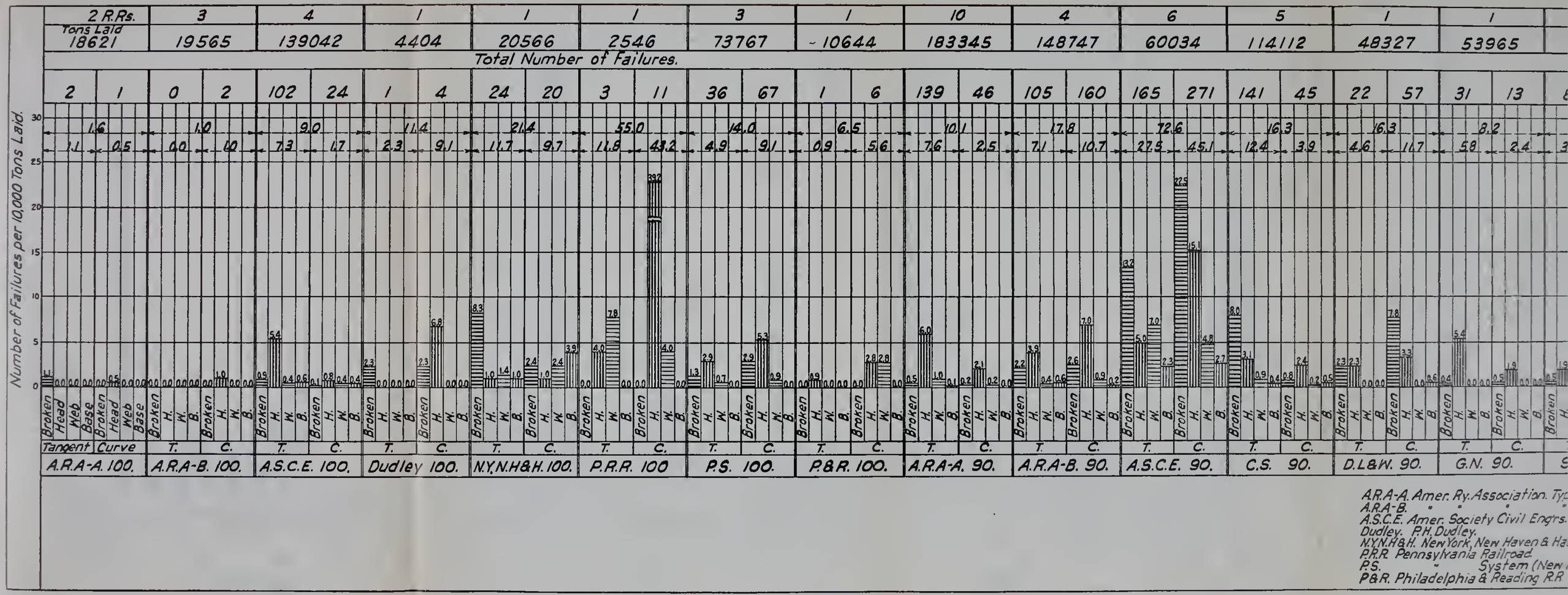
Comparison between different SECTIONS OF RAIL.

BESSEMER STEEL.

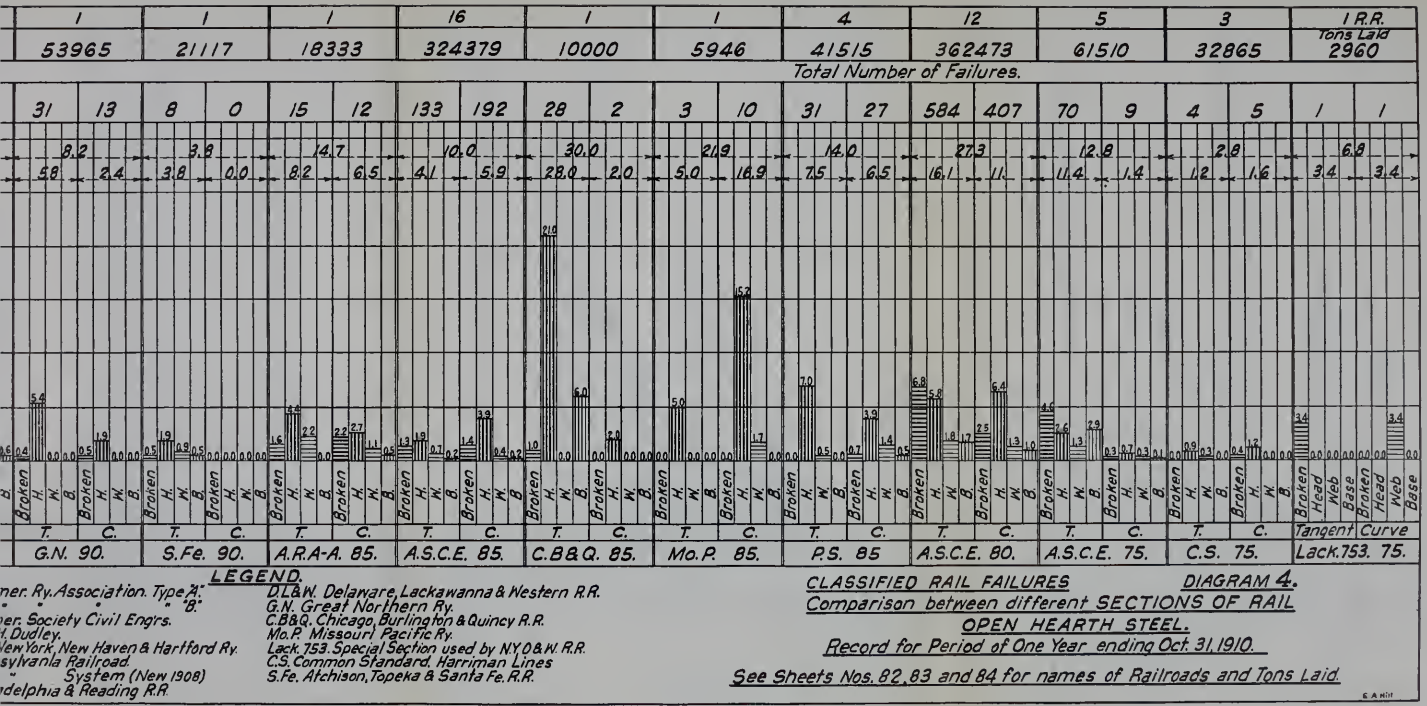
Record for Period of One Year ending Oct. 31, 1910.

See Sheets Nos. 77, 78, 79, 80 and 81 for names of Railroads and Tons Laid.

G.A.H.



A.R.A-A. Amer. Ry. Association. Typ
A.R.A-B. " " "
A.S.C.E. Amer. Society Civil Engrs.
Dudley. P.H. Dudley.
N.Y.N.H&H. New York, New Haven & Ha
P.R.R. Pennsylvania Railroad.
P.S. " System (New
P&R. Philadelphia & Reading R.R.



LEGEND.

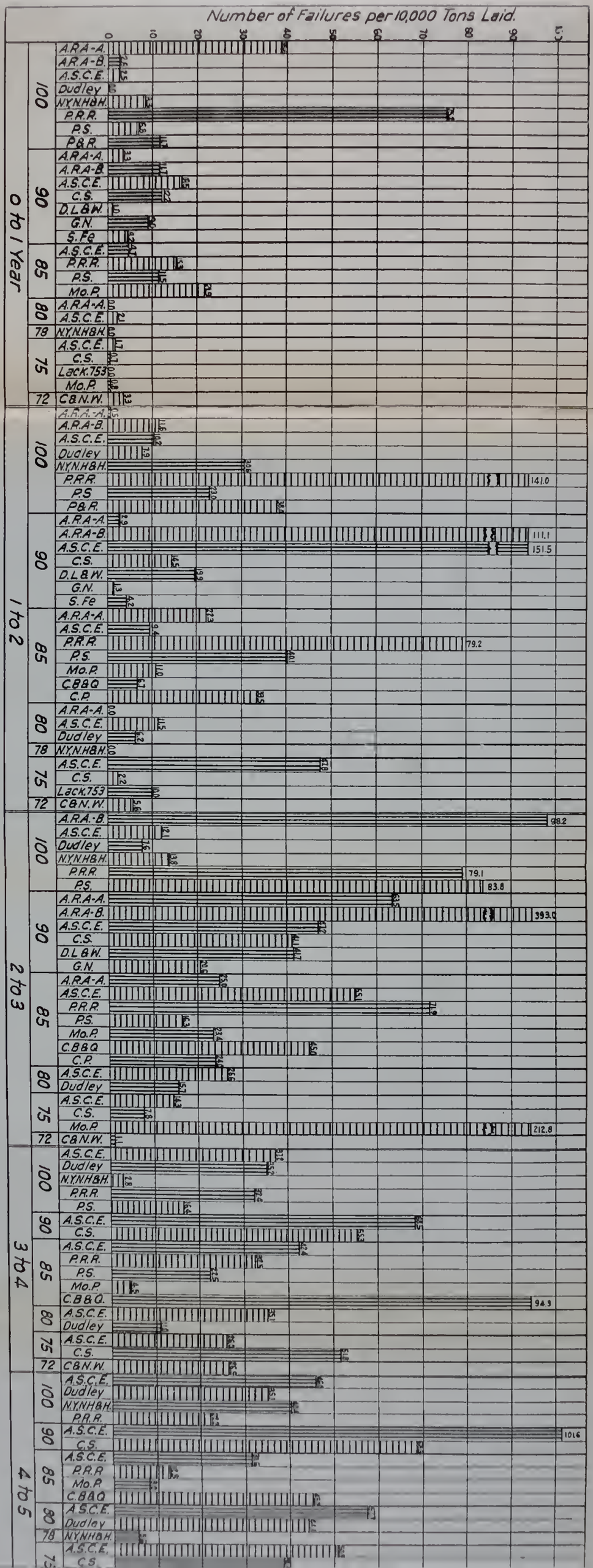
ner. Ry. Association. Type "A"
" " "B"
ner. Society Civil Engrs.
t. Dudley.
New York, New Haven & Hartford Ry.
sylvania Railroad.
" System (New 1908)
delphia & Reading R.R.

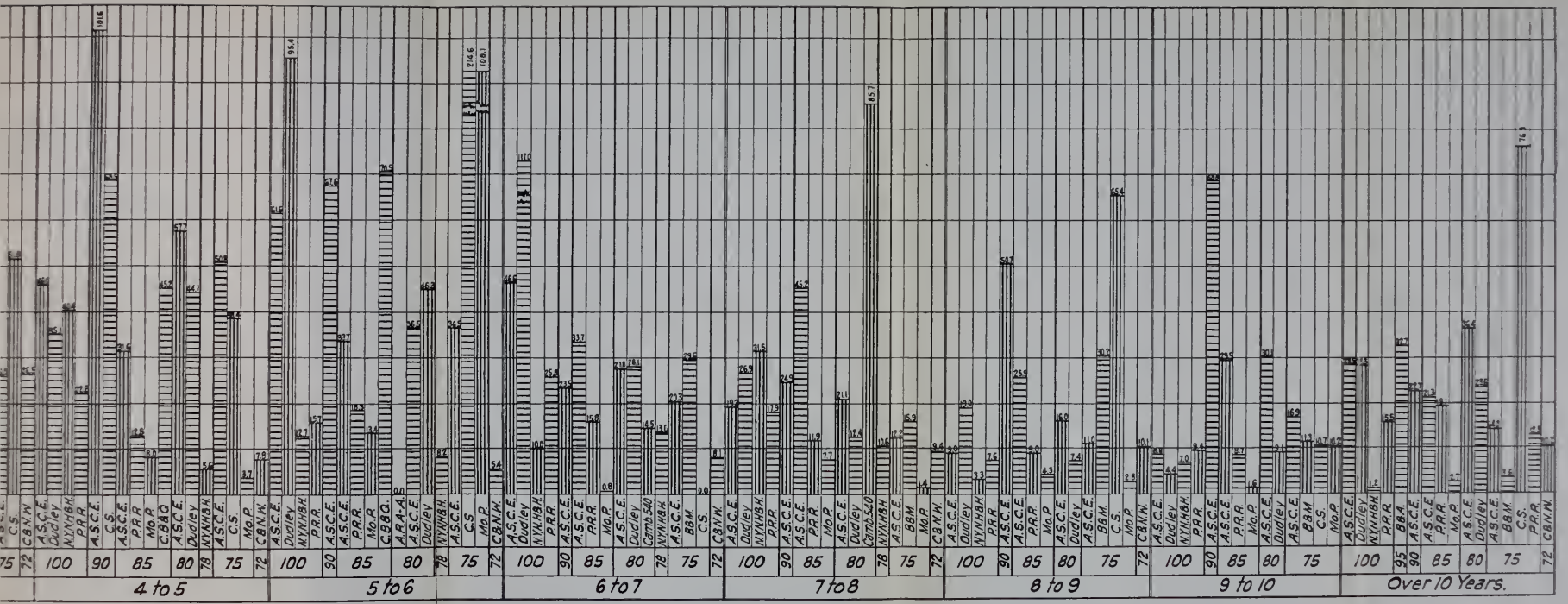
D.L&W. Delaware, Lackawanna & Western R.R.
G.N. Great Northern Ry.
C.B&Q. Chicago, Burlington & Quincy R.R.
Mo.P. Missouri Pacific Ry.
Lack. 753. Special Section used by NYO&W. R.R.
C.S. Common Standard. Harriman Lines
S.Fe. Atchison, Topeka & Santa Fe. R.R.

CLASSIFIED RAIL FAILURES DIAGRAM 4.
Comparison between different SECTIONS OF RAIL
OPEN HEARTH STEEL.
Record for Period of One Year ending Oct. 31, 1910.

See Sheets Nos. 82, 83 and 84 for names of Railroads and Tons Laid.

E.A.Hill


Number of Failures per 10,000 Tons Laid.
0
10
20
30
40
50
60
70
80
90
100
0 to 1 Year
1 to 2
2 to 3
3 to 4
4 to 5
A.R.A-A.
A.R.A-B.
A.S.C.E.
Dudley
N.Y.N.H&H.
P.R.R.
P.S.
P&R.
C.S.
D.L&W.
G.N.
S.Fe
Mo.P.
C.B&Q
C.P.
Lack.753
C.B&N.W.
N.Y.N.H&H.
141.0
111.1
151.5
79.2
98.2
79.1
83.8
393.0
212.8
94.3
101.6



LEGEND

ARA-A Amer Ry Association Type "A"
ARA-B " " "B"
ASCE Amer Society Civil Engrs
Dudley Prof Dudley
NYNHaH New York New Haven & Hartford Ry
PRR Pennsylvania Railroad
PS " System (Now 1908)
P&R Philadelphia & Reading RR
B&A Boston & Albany RR
DL&W Delaware Lackawanna & Western RR
GN Great Northern Ry
C.B&Q Chicago Burlington & Quincy RR
MoP Missouri Pacific Ry
Cambria 340 Special Section used by T&O.C.Ry
C&NW Chicago & North-Western Ry
B&M Boston & Maine RR
CS Common Standard Harriman Lines
S.Fe Atchison, Topeka & Santa Fe RR
Lack 133 Special Section used by N.Y.O.&W RR
CP Canadian Pacific RR

CLASSIFIED RAIL FAILURES. DIAGRAM 5.
Comparison of Failures at different LENGTHS OF LIFE.
ALL KINDS OF STEEL.
Record for Period of One Year ending Oct 31, 1910.

See Sheets Nos. 77 to 84 inclu. for names of Railroads and Tons Laid.

CLASSIFIED RAIL FAILURES.

Diagram 1.

COMPARISON BETWEEN DIFFERENT WEIGHTS OF RAIL—BESSEMER STEEL.

Diagram 2.

COMPARISON BETWEEN DIFFERENT WEIGHTS OF RAIL—OPEN-HEARTH STEEL.

Diagram 3.

COMPARISON BETWEEN DIFFERENT SECTIONS OF RAIL—BESSEMER STEEL.

Diagram 4.

COMPARISON BETWEEN DIFFERENT SECTIONS OF RAIL—OPEN-HEARTH STEEL.

Diagram 5.

COMPARISON OF FAILURES AT DIFFERENT LENGTHS OF LIFE—ALL KINDS OF STEEL.

As a further statement, I will give you the result of the Titanium rail placed in track on one of our branch lines—the Tyrone Division.

Four tons of 85-lb. P.R.R. section of rail, with a percentage of Titanium, was laid on a 13-deg. 50-min. curve, Tyrone Division, P.R.R., in September, 1908. The composition was as follows:

Carbon	.53
Phosphorus	.074
Manganese	.91
Silicon	.098
Sulphur	.056

This rail was removed worn out in November, 1909 (14 months).

Ordinary Bessemer lasts on this curve 12 to 15 months; hence the Titanium rail did not show any marked superiority.

We have another test of about 95 tons of Titanium rail, which was laid on the Buffalo Division in June, 1910. The time has been too short to produce results, but it may be of value for a future report.

Respectfully,

(Signed) Jos. T. Richards,
Chief Engineer M. W., and Member of Committee.

Exhibit A.

COMPARATIVE TEST OF BESSEMER, OPEN-HEARTH AND NICKEL STEEL RAIL ON PENNSYLVANIA RAILROAD.

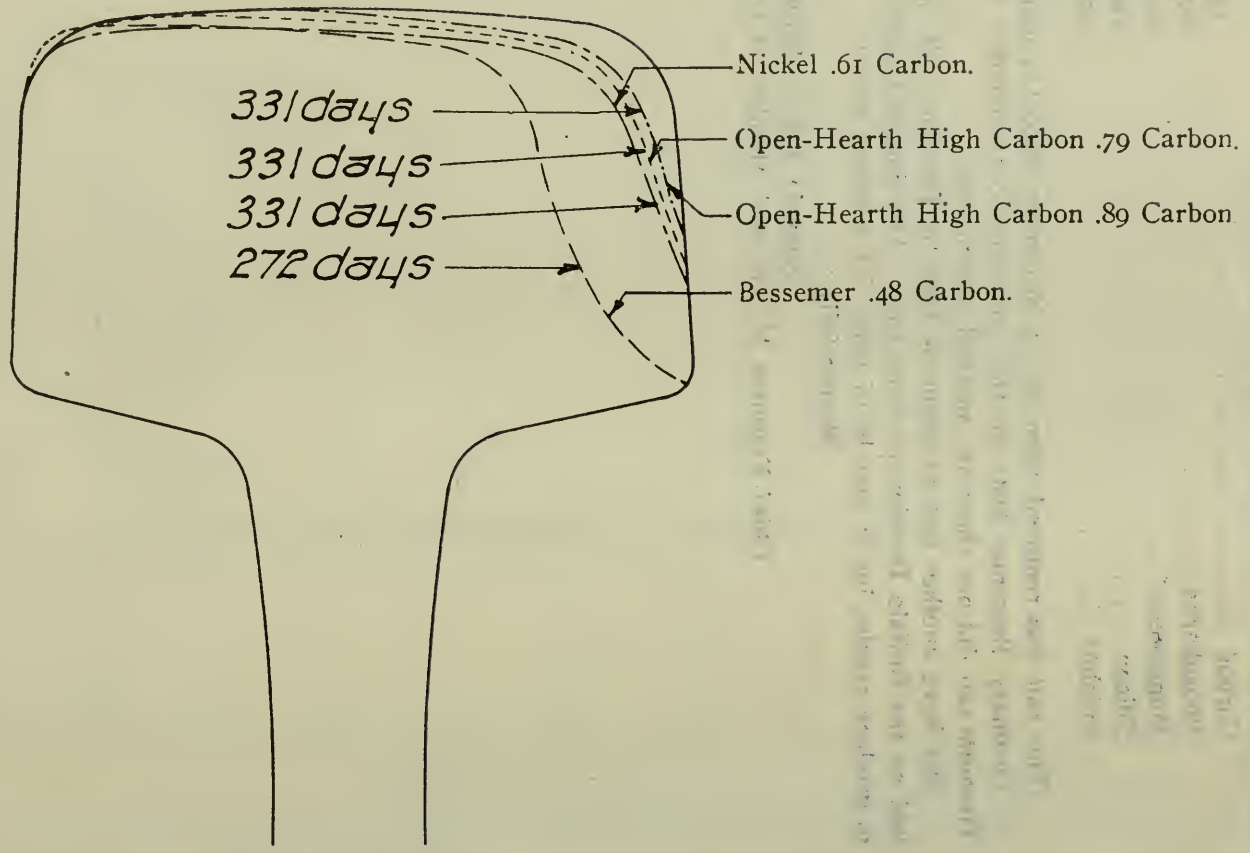


FIG. 1. HIGH RAIL.

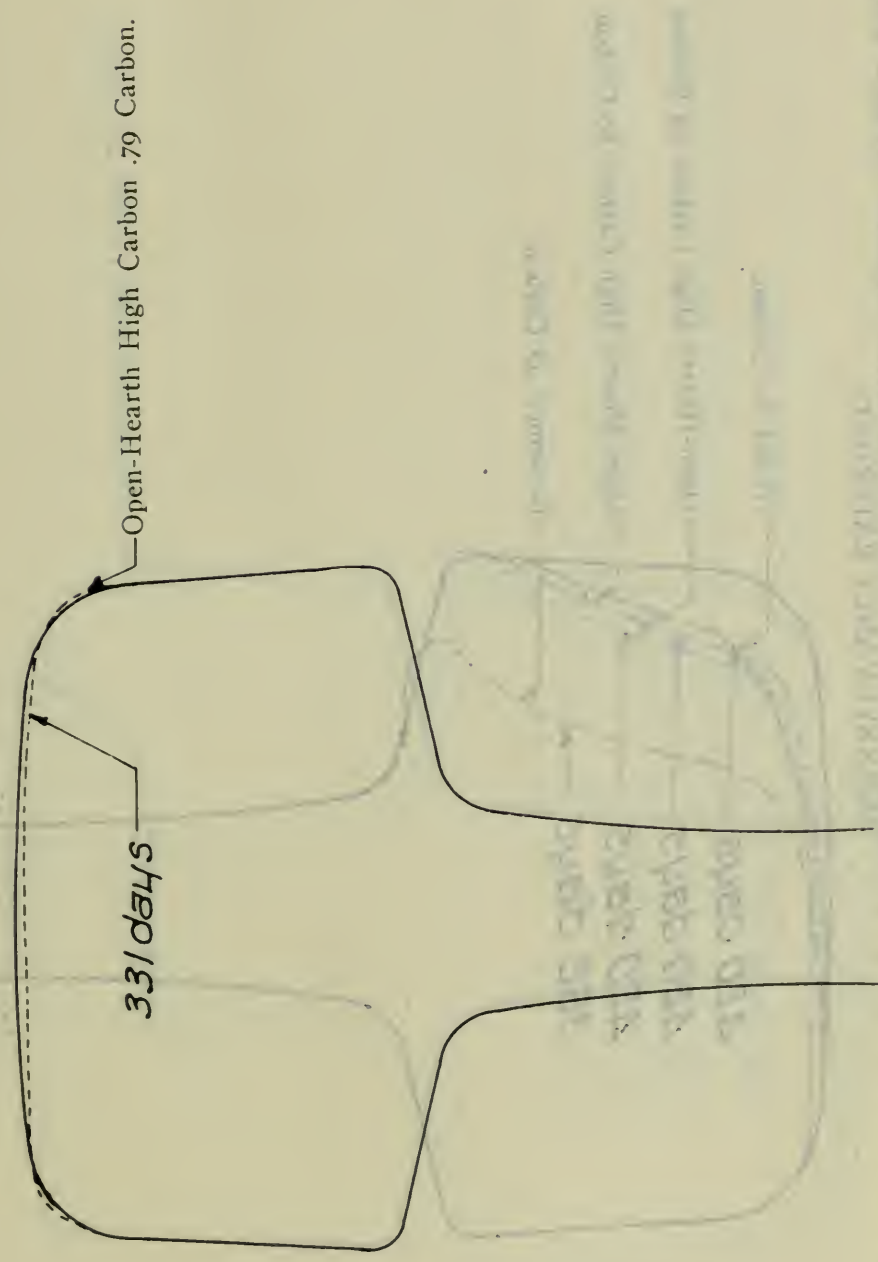


FIG. 1. LOW RAIL.

Exhibit A—Continued.

COMPARATIVE TEST OF BESSEMER, OPEN-HEARTH AND NICKEL STEEL RAIL ON PENNSYLVANIA RAILROAD.

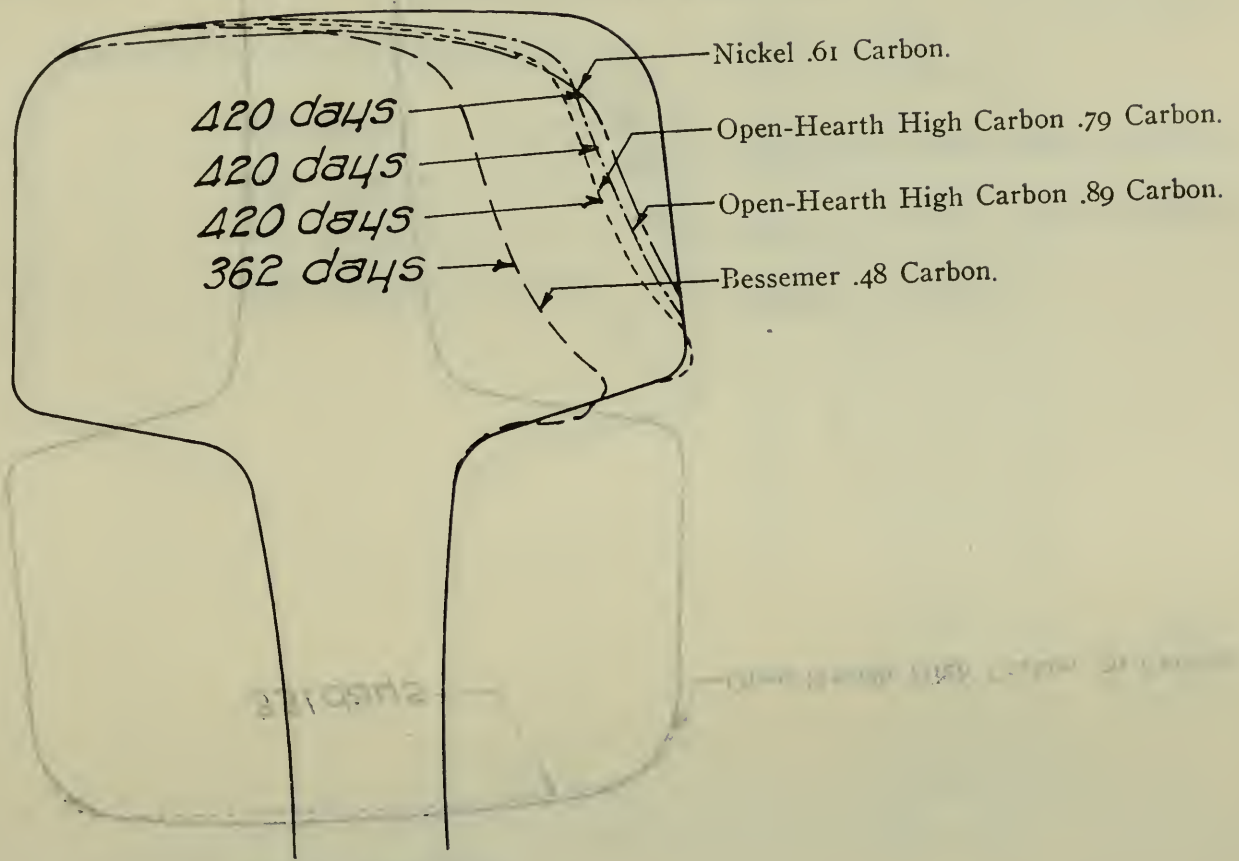


FIG. 2. HIGH RAIL.

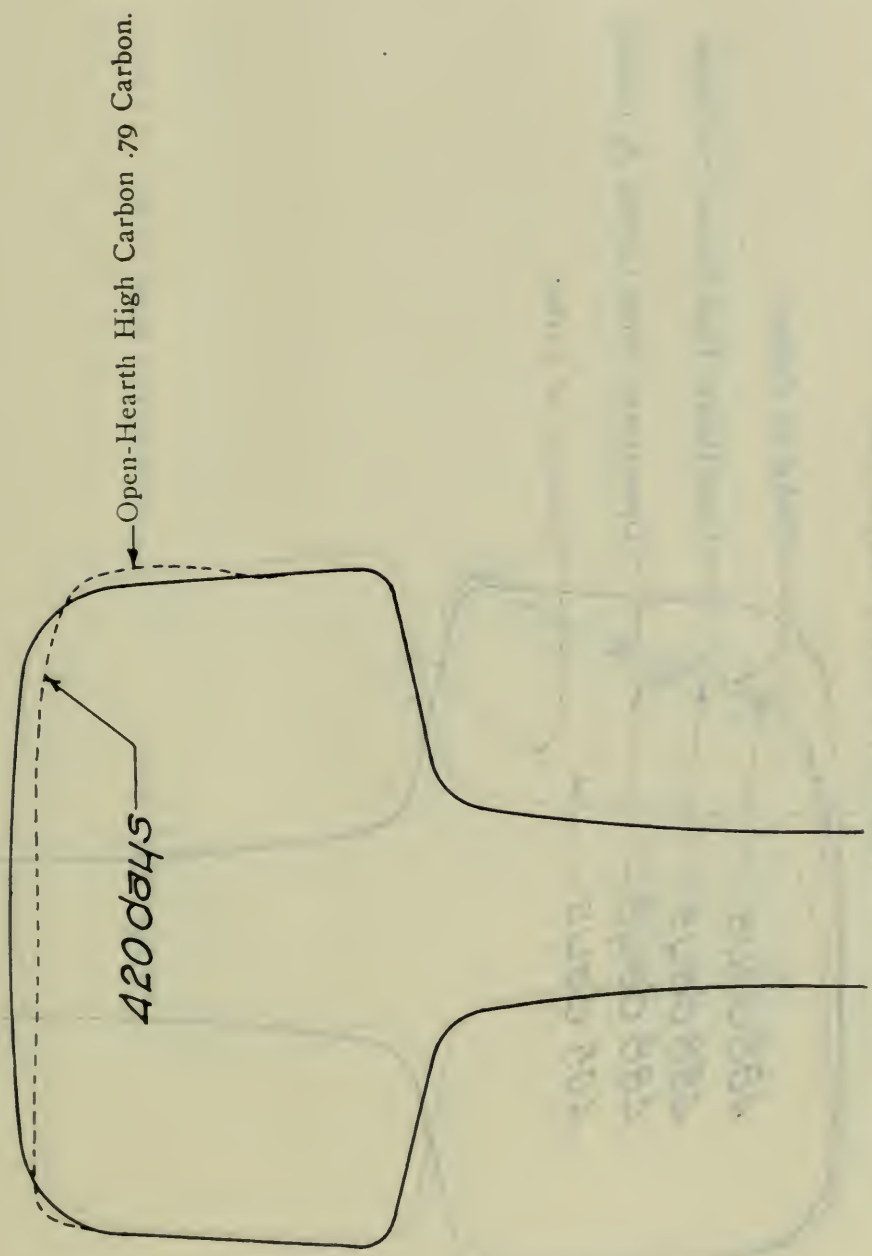


FIG. 2. LOW RAIL.

Exhibit A—Continued.

COMPARATIVE TEST OF BESSEMER, OPEN-HEARTH AND NICKEL STEEL RAIL ON PENNSYLVANIA RAILROAD.

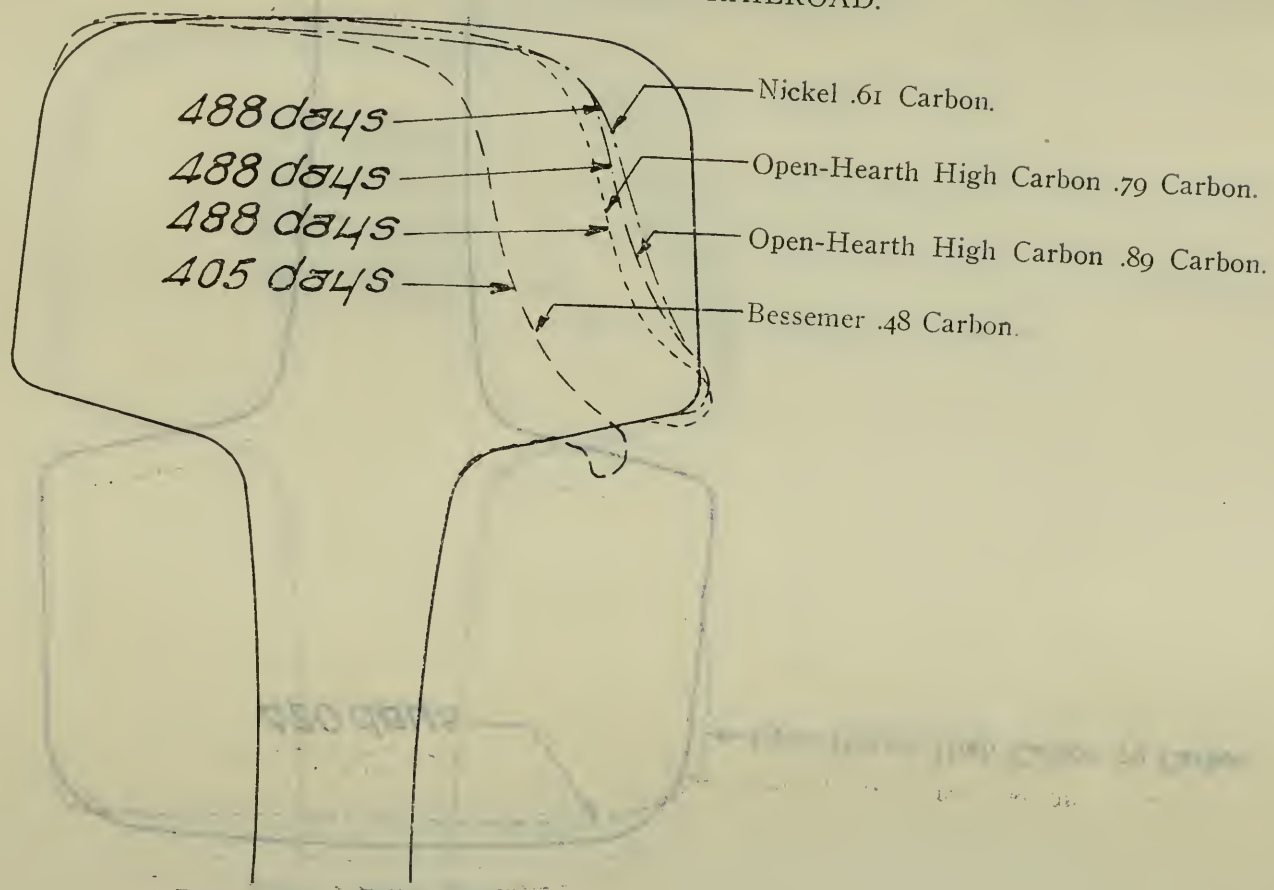


FIG. 3. HIGH RAIL.

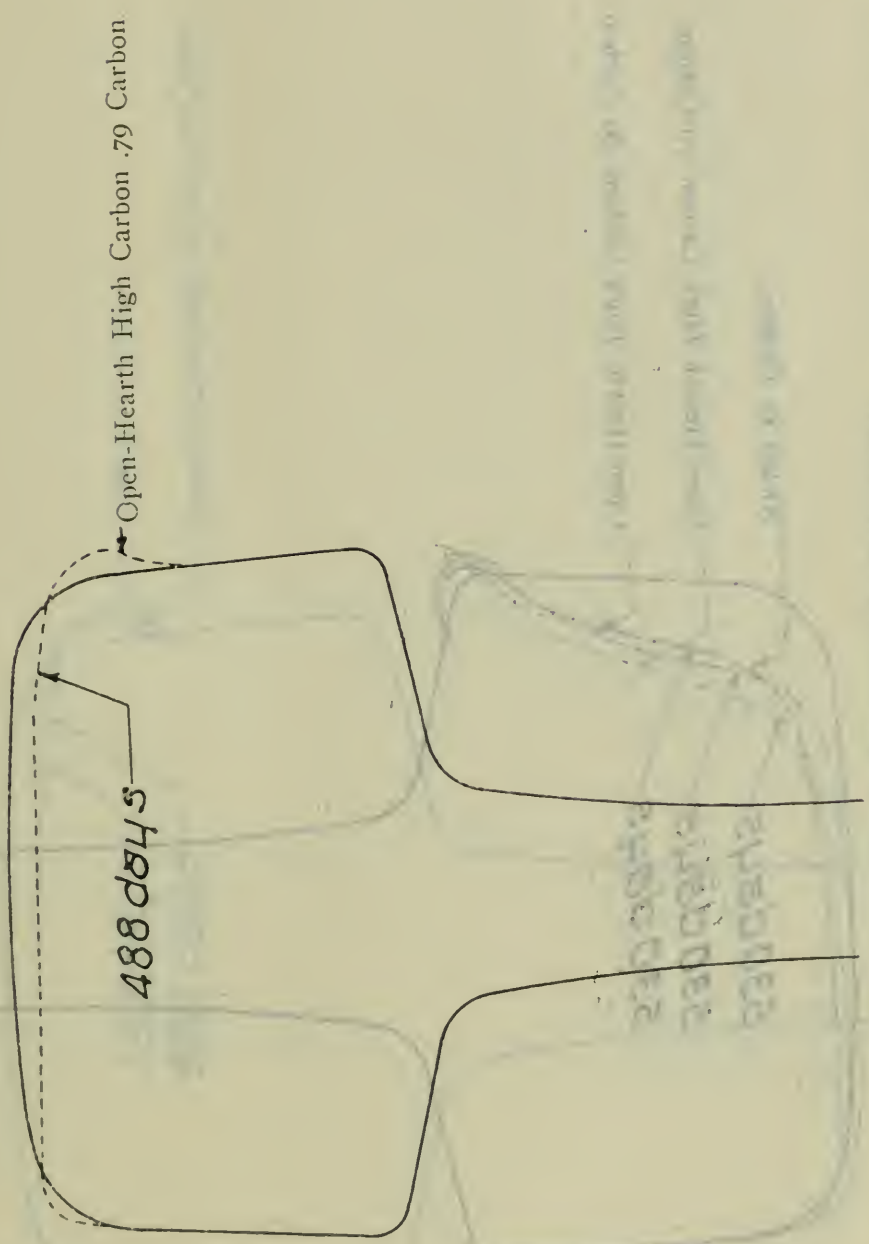


FIG. 3. LOW RAIL.

Exhibit A—Continued.

COMPARATIVE TEST OF BESSEMER, OPEN-HEARTH AND NICKEL STEEL RAIL ON PENNSYLVANIA RAILROAD.

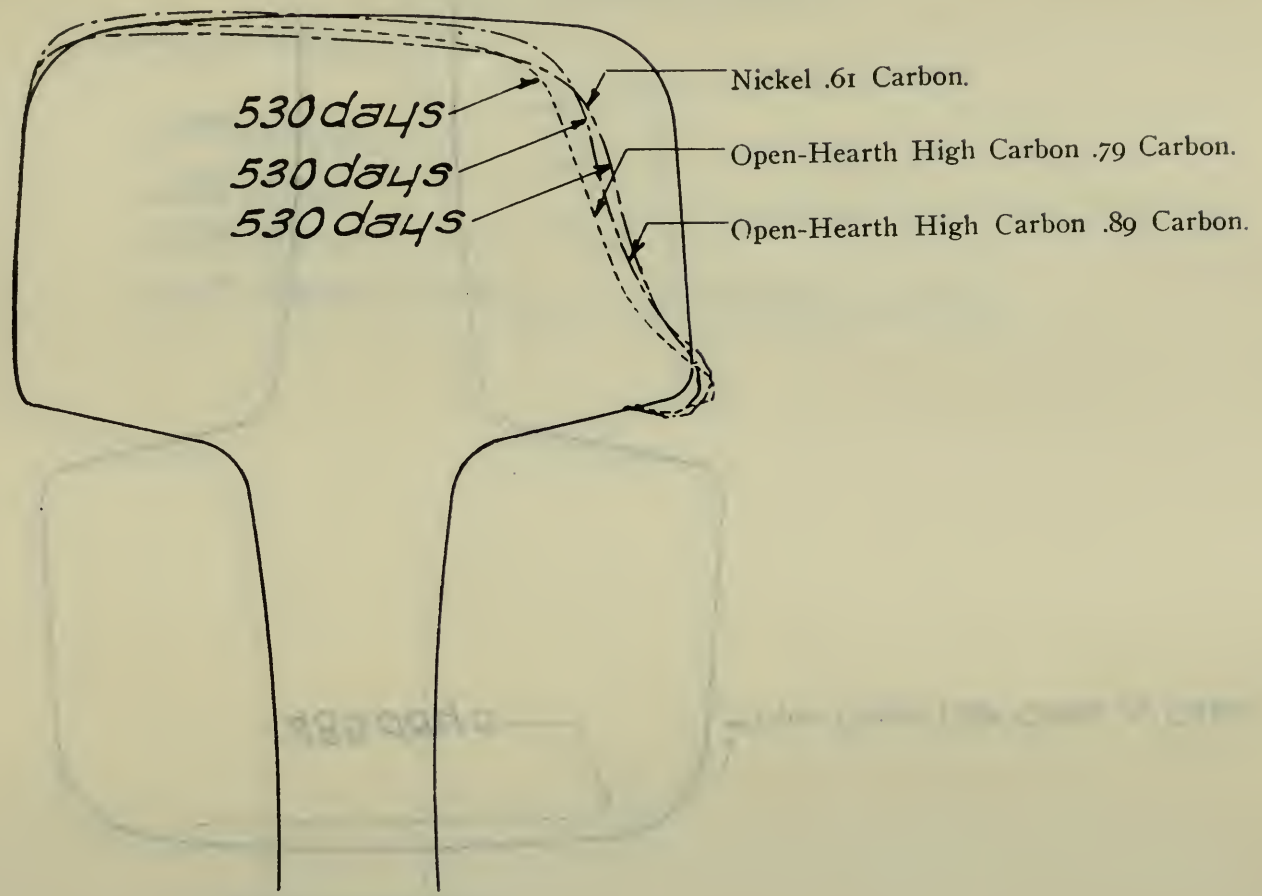


FIG. 4. HIGH RAIL.

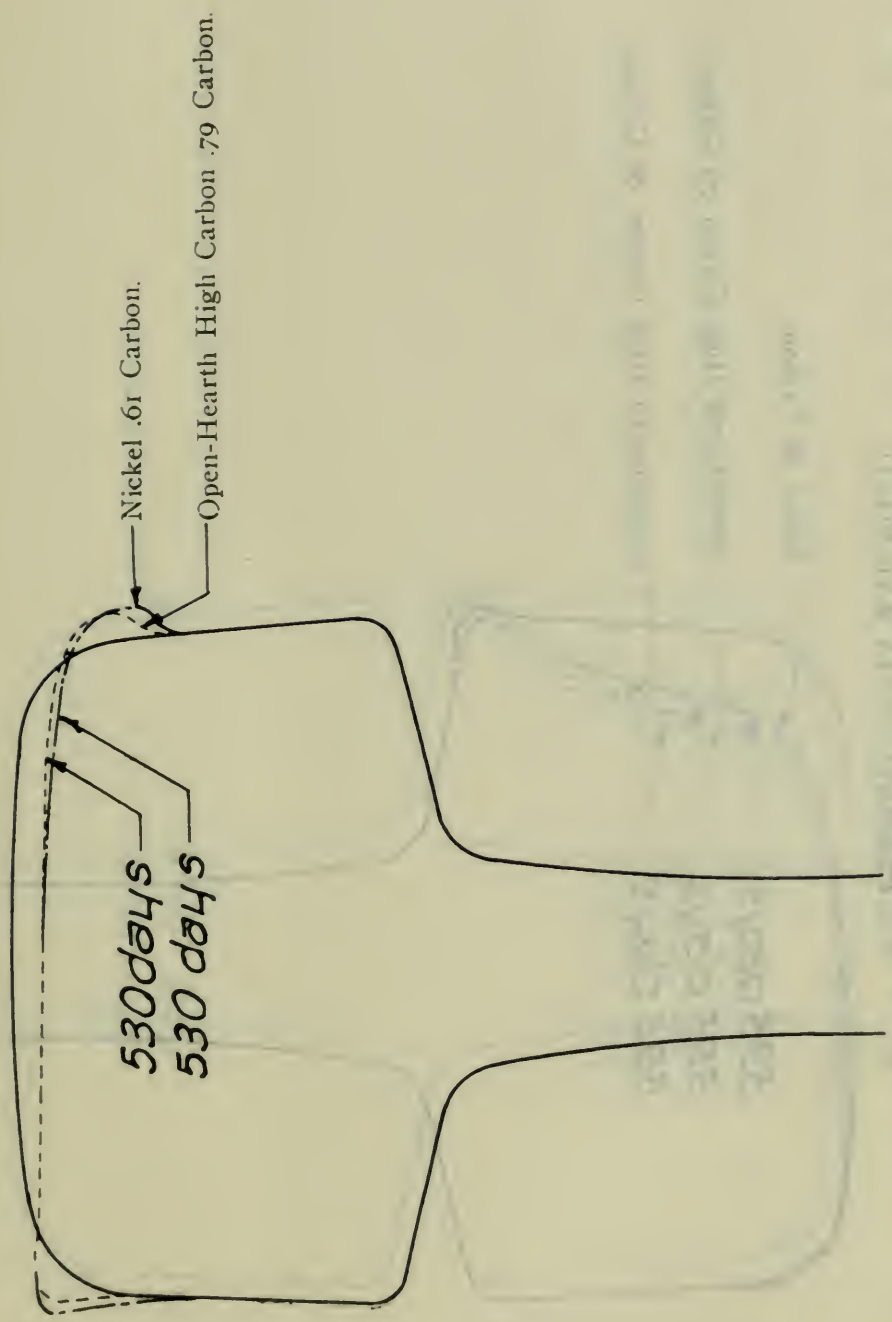


FIG. 4. LOW RAIL.

Exhibit A—Continued.

COMPARATIVE TEST OF BESSEMER, OPEN-HEARTH AND NICKEL STEEL RAIL ON PENNSYLVANIA RAILROAD.

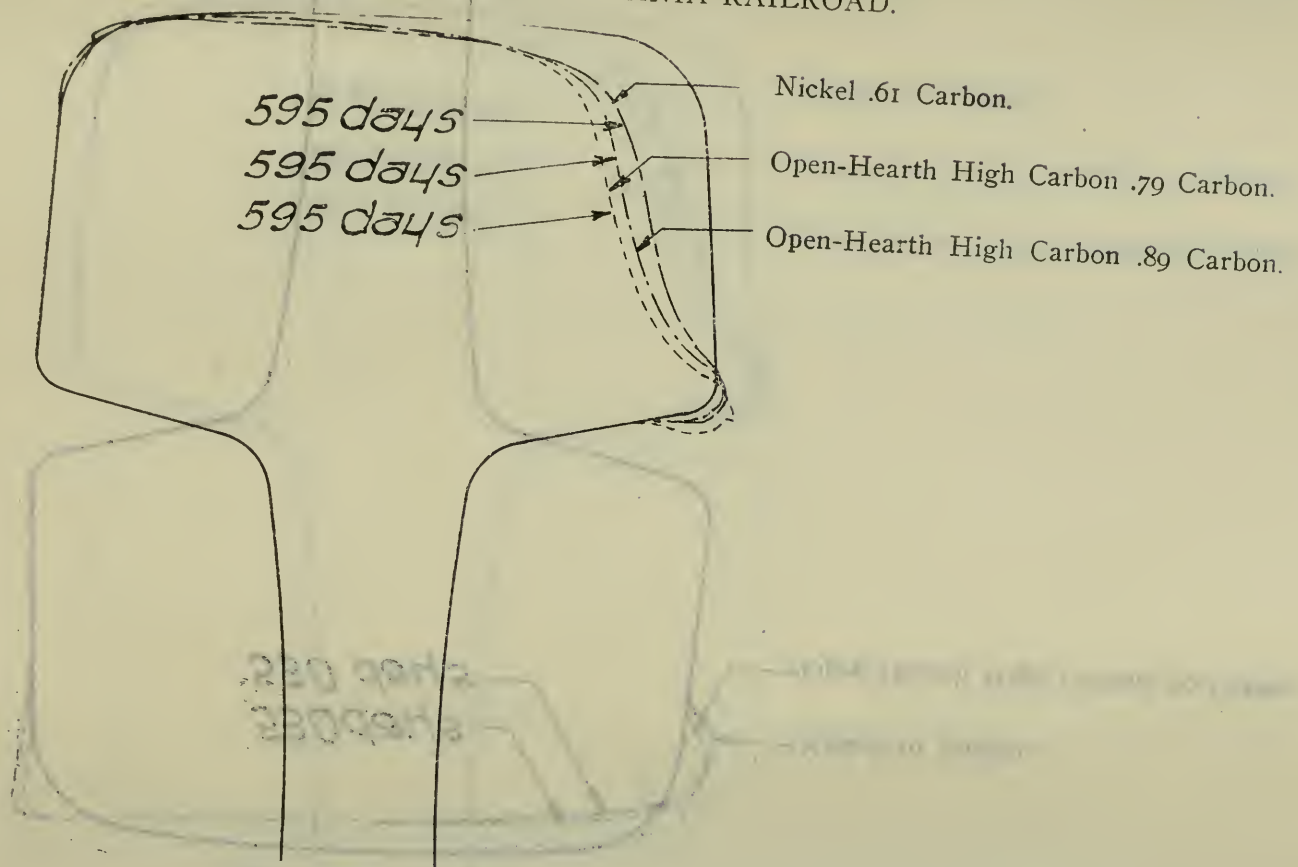


FIG. 5. HIGH RAIL.

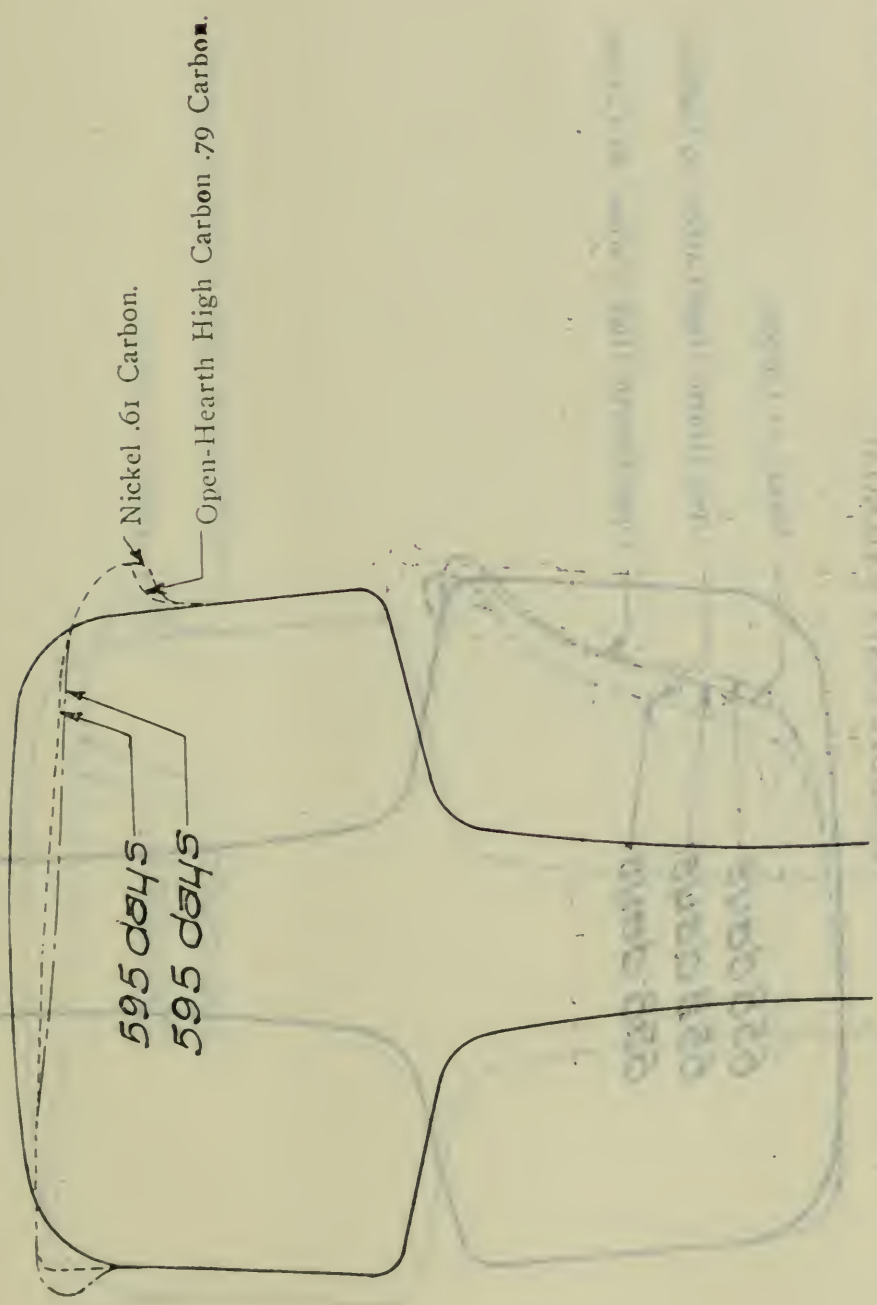


FIG. 5. LOW RAIL.

COMPARATIVE TEST OF BESSEMER, OPEN-HEARTH AND NICKEL STEEL RAIL ON PENNSYLVANIA RAILROAD.

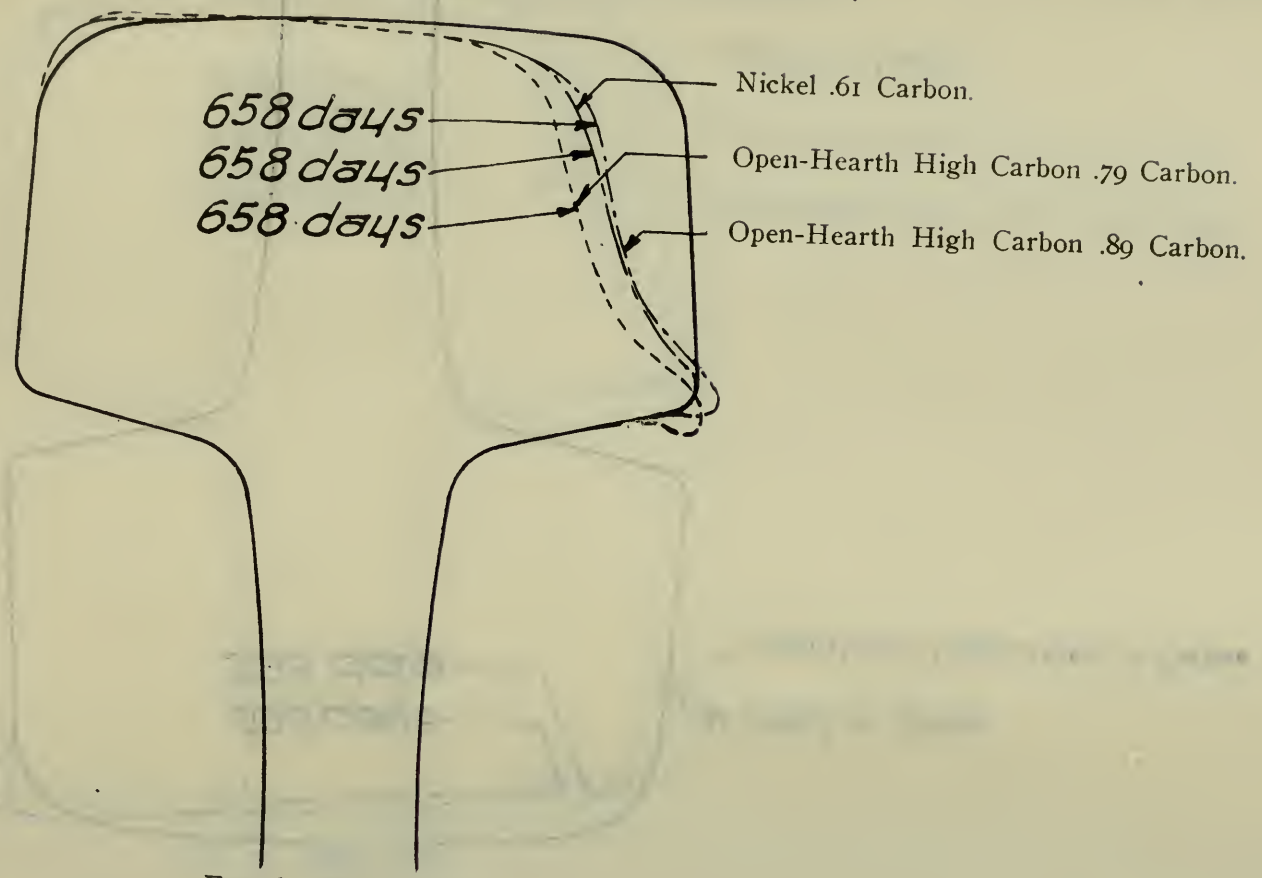


FIG. 6. HIGH RAIL.

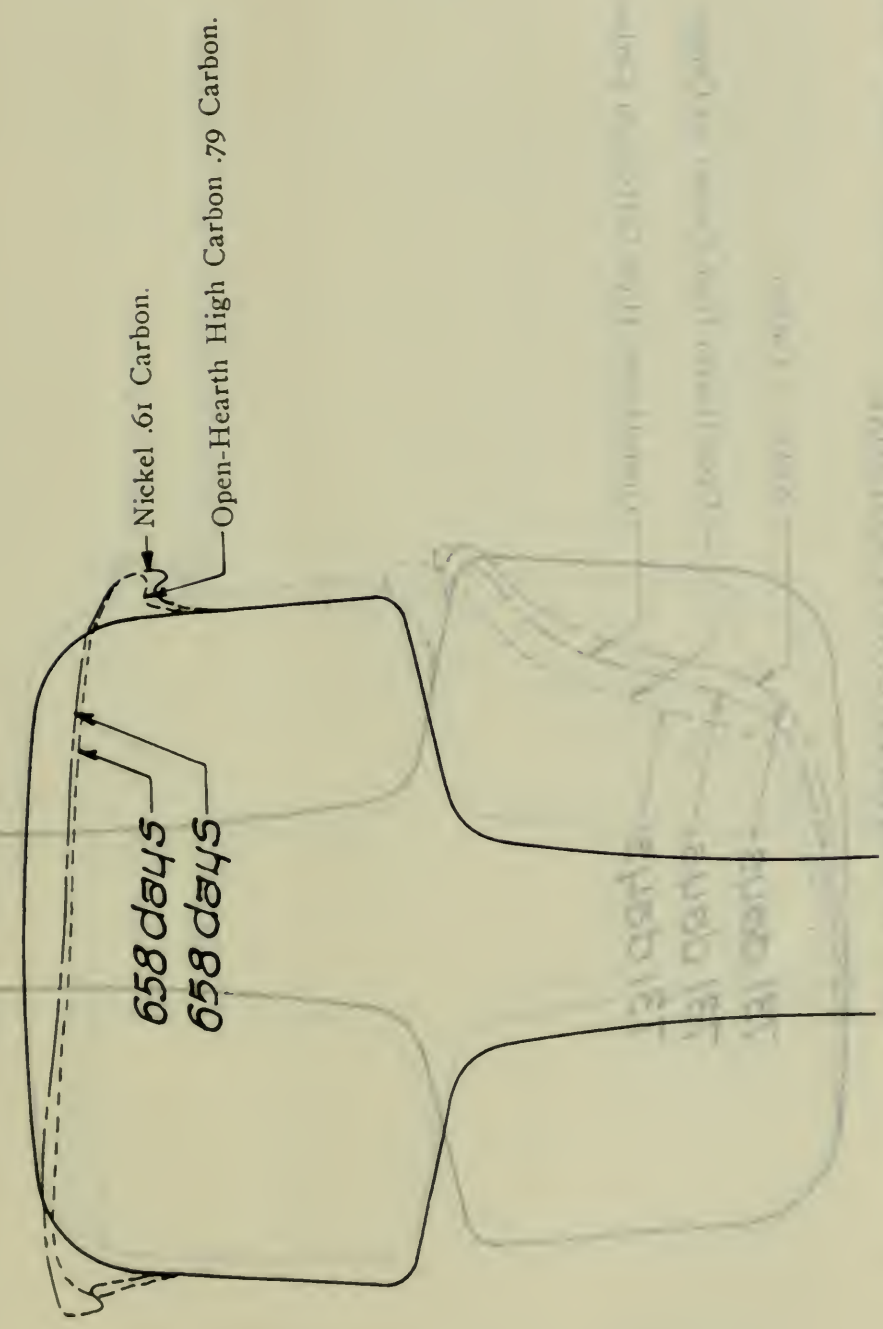


FIG. 6. LOW RAIL.

Exhibit A—Continued.

COMPARATIVE TEST OF BESSEMER, OPEN-HEARTH AND NICKEL STEEL RAIL ON PENNSYLVANIA RAILROAD.

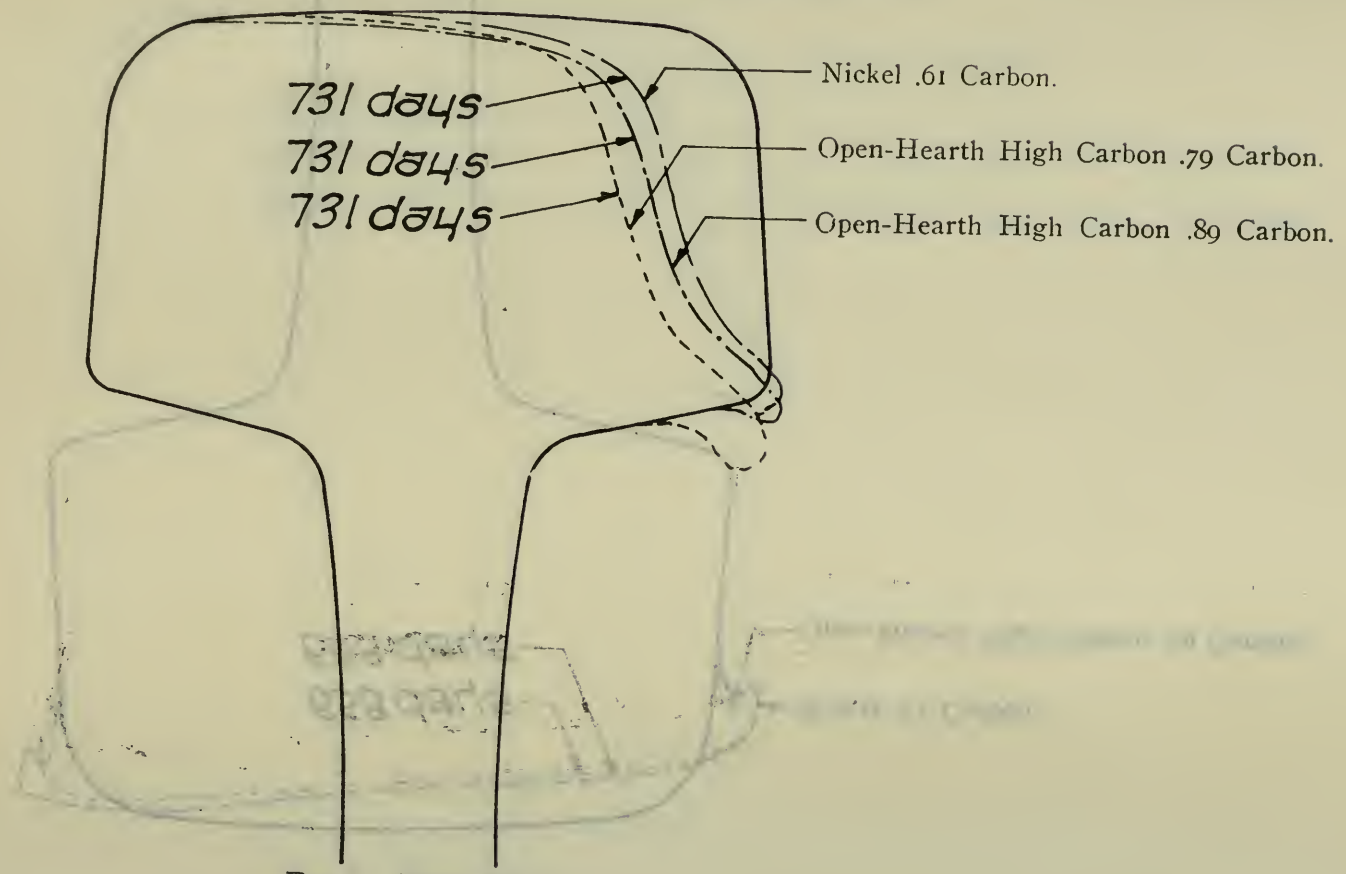


FIG. 7. HIGH RAIL.

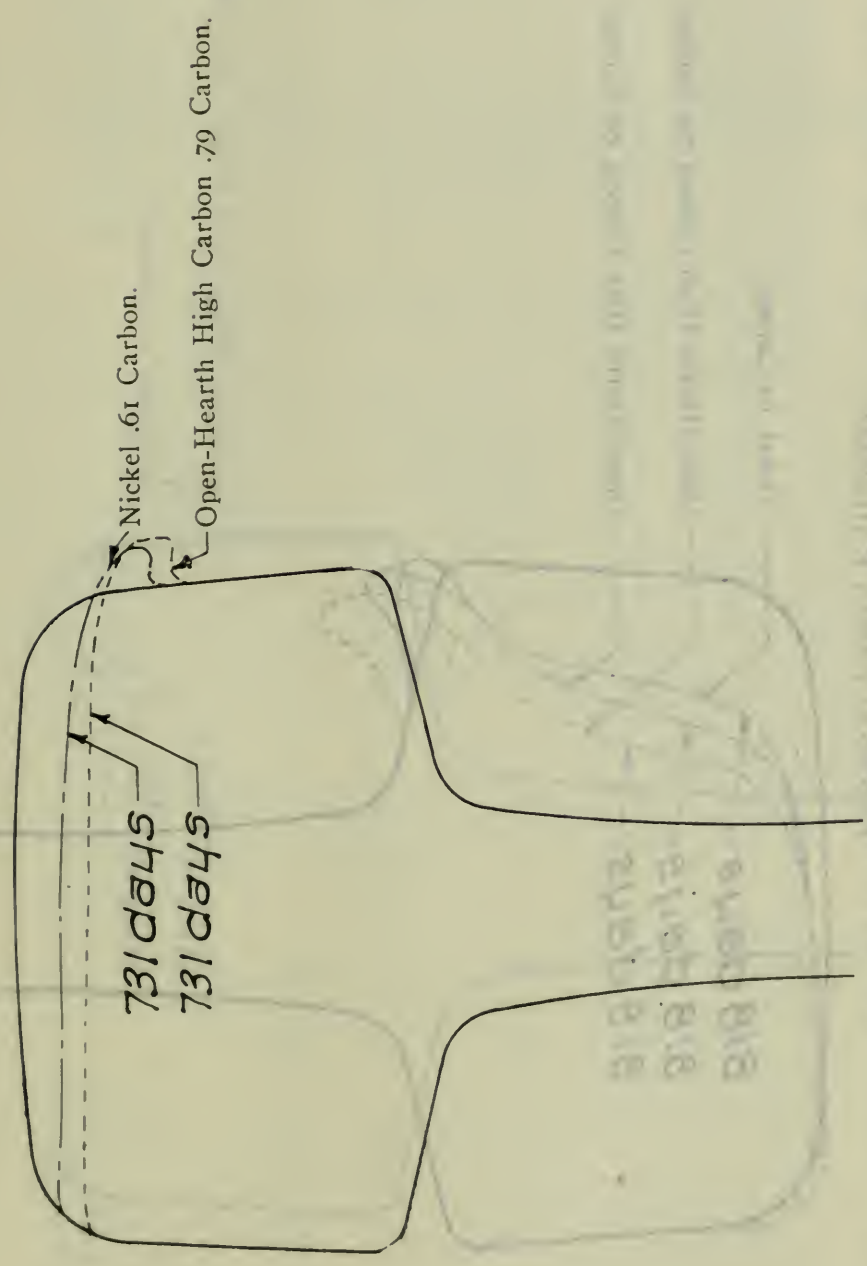


FIG. 7. LOW RAIL.

Exhibit A—Continued.

COMPARATIVE TEST OF BESSEMER, OPEN-HEARTH AND NICKEL STEEL RAIL ON PENNSYLVANIA RAILROAD.

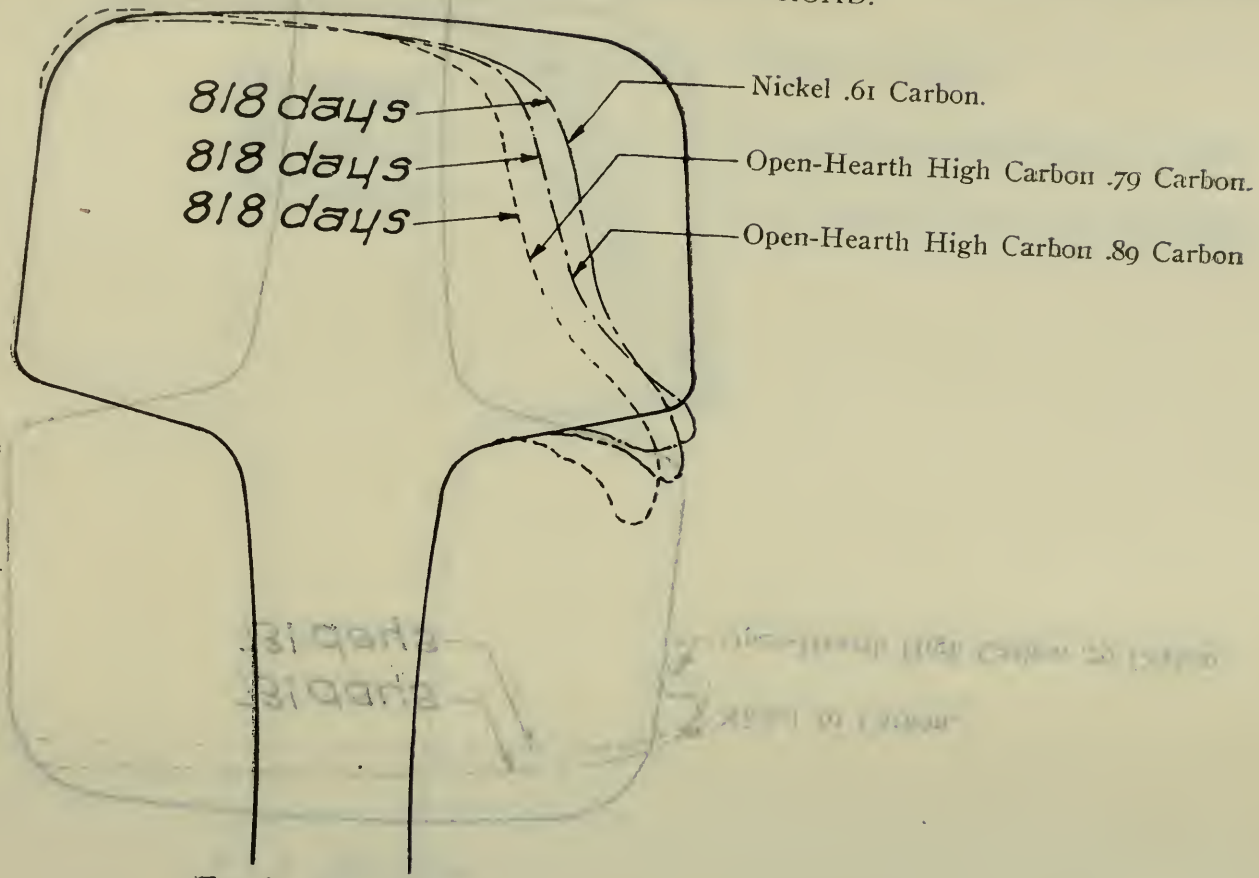


FIG. 8. HIGH RAIL.

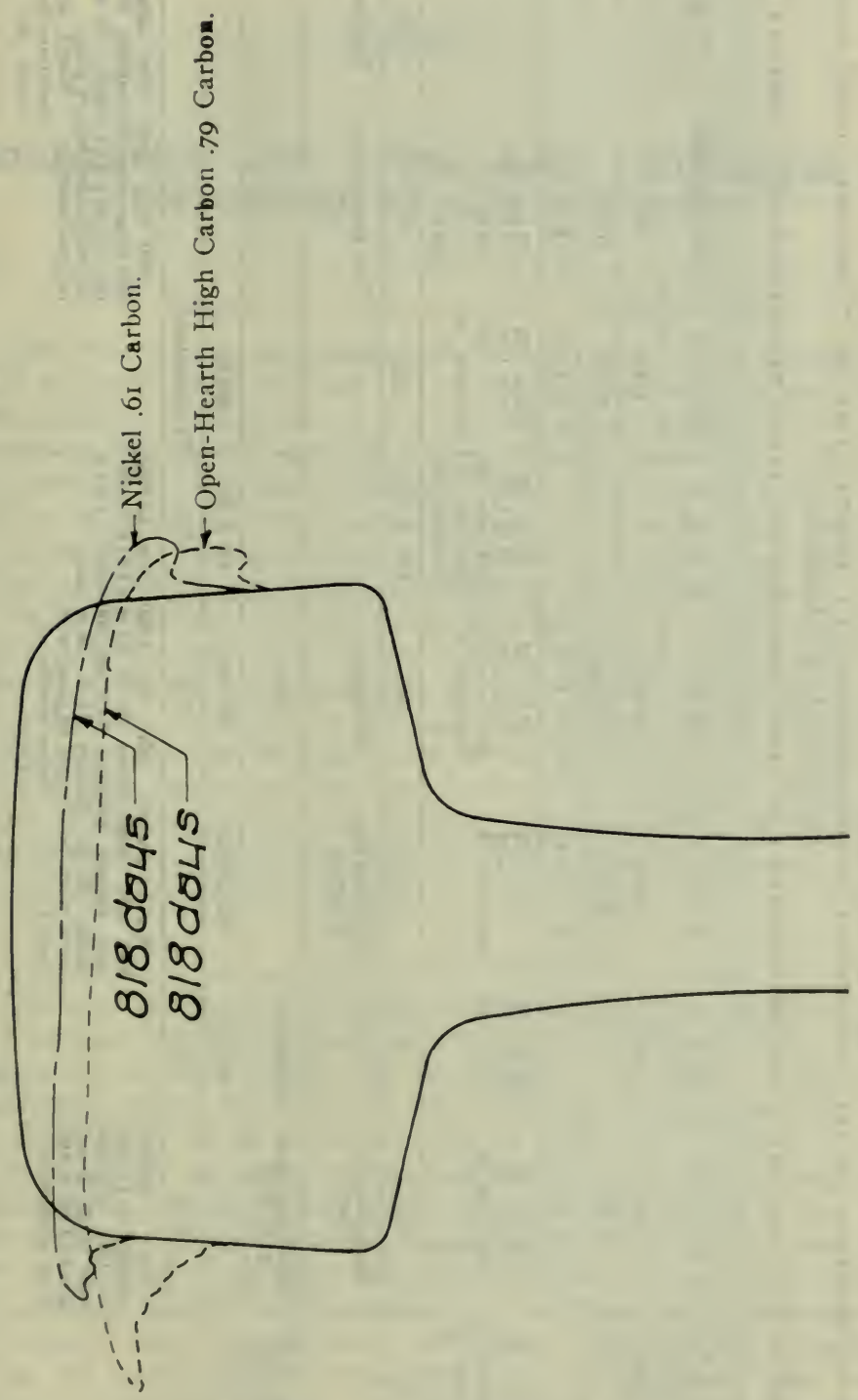


FIG. 8. LOW RAIL.

EXHIBIT B—INFORMATION RELATIVE TO SERVICE OF OPEN-HEARTH RAIL, COMPILED BY JOS. T. RICHARDS, CHIEF ENGINEER M. OF W. PENNSYLVANIA RAILROAD.

SPECIAL O.-H. RAIL WITH LOW PHOSPHORUS AND LARGE DISCARD—ROLLED BY BETHLEHEM STEEL COMPANY IN 1908.

	A. T. & S.-F. R. R.	B. & O. R. R.	C. B. & Q. R. R.	C. R. R. of N. J.	D. & H. Co.	D. L. & W. R. R.	Erie R. R.	LONG ISLAND	L. V. R. R.	UNION PACIFIC
Tons Laid	16,846	1,000	10,000	5,502	1,000		1,000	900		5,000
Wt. per yard		90 lbs.		90 lbs.	90 lbs.		90 lbs.	100 lbs.		75 lbs.
Section		A. R. A.-B.		A. S. C. E.	A. S. C. E.		A. S. C. E.	A. S. C. E.		C. S.
Analysis Car.	.60 to .70	.65 to .75	.55 to .67	.54 to .64	.57 to .67	.67 to .80	.54 to .64	.70 to .78		
Analysis Man.	.70 to 1.00	.75 to 1.00	.70 to 1.00	.82	.70 to 1.00	.80 to 1.05	.70 to 1.00	.71 to .80		
Analysis Phos.	Not over .04	Not over .06	.04 to .045	Not over .03	Not over .04	Not over .04	.06	.02 to .03	.03	Not over .04
Analysis Sil.	Not over .20	.10 to .20			Not over .20	Not over .02	Not over .20			
Analysis Sul.	Not over .06					Not over .06		.04 to .06		
Discard	9%	9%		9%	15%	15% & 20%	9%	9%	20%	31.7%
Wear		Exceptionally Good	Good	No better than Bessemer	Satisfactory			Not appreciable yet	Excellent	No better than ordinary O.-H. Rail
Failures	7 per 10,000 tons laid	More than other O. H. Rail	Numerous		None					
Price	$31.00		$34.50	No increase	$33.00	$33 & $35	$30.00			
Justified		Yes	No		Yes	No.	Problematical			No.
		Have recommended O.-H. exc. for 1911. 9% discard at $3.00 per ton add'nal is the most economical		Rails proved soft and mushy and carbon was made .65 to .75 with much better results.	Also laid 1,000 tons .55 to .65 c. and .05 p. and 800 tons .54 to .64 c. and .06 phos. with same results as above.	Are having plain O.-H. rolled this year.		Will take accurate measurements in comparison with other rail in a few months.	Now using .1% titanium. 15% discard .82 carbon. .04 phos. Would not pay premium for phos. below .04.	Confidential 7-rails rolled from each ingot—lower 5 classed as "Premium" rails.

Appendix C.

SEGREGATION AND OTHER RAIL PROPERTIES A INFLUENCED BY SIZE OF INGOT.

By

M. H. WICKHORST, Engineer of Tests, Rail Committee.

This report covers an investigation to throw light on the relationship of the size of ingots of Bessemer rail steel to the segregation of the metalloids, locations of pipes and blow holes, and the properties of the rails. A series of five ingots was made of the following bottom sizes, all 5 ft. high, namely, 12 in. x 12 in., 15 in. x 15 in., 18 in. x 18 in., 20 in. x 24 in. and 25 in. x 30 in. These were split open, one-half used to obtain borings for a chemical survey of the ingot, and the other half for etching. Another similar set of ingots was rolled into rails with only sufficient discard from the top of the bloom to allow rolling into rail, and the entire rail bars from these ingots were used for drop tests, etchings and chemical analyses, except that no rails were rolled from the 12-in. ingot, as an attempt to do so resulted in a "cobble" on account of the small size of the ingot. Finally, two other sets of rails are to be rolled from the 15 in. x 15 in., 18 in. x 18 in., 20 in. x 24 in. and 25 in. x 30 in. ingots. These are intended for service tests on the Cumberland Division of the Baltimore & Ohio Railroad, one set on the high rail of a 5-degree or 6-degree curve, and the other set on the low rail.

MANUFACTURE.

The steel used was all Bessemer steel made from Lake Superior ores. The iron from the blast furnaces was poured into a mixer, from here it was weighed into a ladle, poured into the converter and blown, scrap steel being added during the blowing. After blowing, spiegel was added to the converter, the metal was poured into an intermediate ladle, then into the pouring ladle and finally into the molds through a 1½-in. nozzle. The various series of ingots were made from different heats, as one set required almost a whole heat, but were all made from steel of about the same composition. The work was done at South Chicago at the South Works of the Illinois Steel Company, who very generously furnished all the material, labor and facilities for splitting, analyzing and otherwise testing the ingots and rails from two heats of steel. As these tests involved considerable expense, the special thanks of the Rail Committee

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are due to the officers of the Illinois Steel Company for their generosity and efficiency in doing this work.

The amounts of materials used to make the two heats are shown in table 1.

TABLE 1—BESSEMER AMOUNTS.

Heat No.	4,520	5,731
Purpose	Ingots	Rails for test
Mixer metal, lbs.	28,100	30,200
Scrap steel, lbs.	2,200	1,800
Spiegel, lbs.	3,520	3,380

Special samples of the mixer metal and the spiegel gave the results shown in tables 2 and 3.

TABLE 2—MIXER METAL.

Heat.	C.	P.	S.	Mn.	Si.
4520	4.00	.091	.032	.70	1.68
5731	3.89	.094	.050	.68	1.18

TABLE 3—SPIEGEL.

Heat.	C.	P.	S.	Mn.	Si.
4520	4.44	.102	....	11.50	1.08
5731	4.30	.085	.010	12.00	1.40

The various Bessemer operations occurred at the times shown in table 4.

TABLE 4—TIME OF BESSEMER OPERATIONS.

Heat	4520	5731
Date	3-23-11	4-5-11
Started blowing	2.19 p. m	10.16 a. m.
Finished blowing	2.31 p. m.	10.27 a. m.
Time used to blow	12 min.	11 min.
Started to pour into ladle	2.32 p. m.	10.29 a. m.
Started to pour into molds	2.38½	10.36 a. m.
Time from finish of blowing to start of pouring into molds	7½ min.	9 min.
Finished pouring into molds	2.49 p. m.	10.46 a. m.

As stated above, five different sizes of ingots were made, and the dimensions and weights of the molds used are shown in table 5. Previous to casting the molds were sprayed with tar. In order to avoid having the size of mold either increase or decrease, as the height of metal in the ladle decreased, the ingots were poured in the following order, 15 x 15, 20 x 24, 12 x 12, 25 x 30 and 18 x 18.

TABLE 5—MOLDS.

Size	12x12	15x15	18x18	20x24	25x30
Height	62¾ in.	63 in.	74½ in.	77½ in.	81 in.

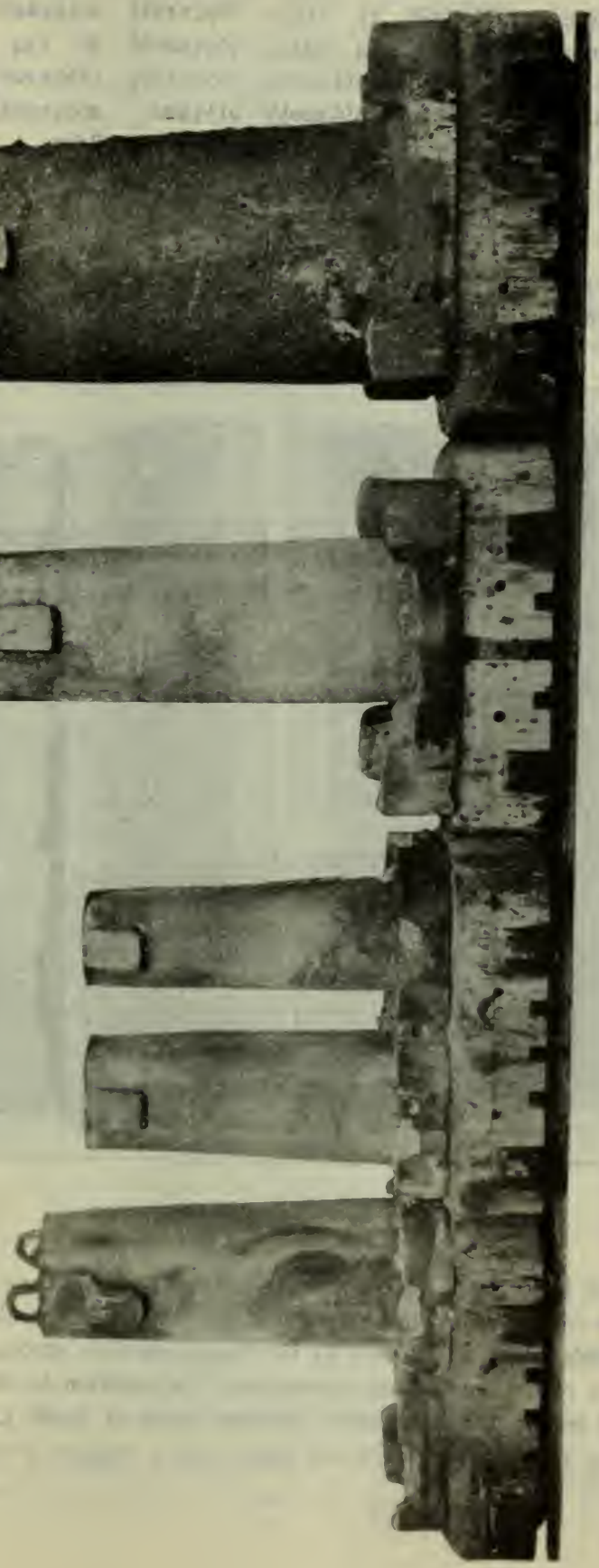


FIG. 1.—MOLDS ON THEIR STOOLS.

Bottom, inside	12⅛x12⅜	15 x15⅛	18¾x18¾	20⅜x24⅜	25¼x30⅜
Bottom, outside	21⅛x21⅛	24 x24½	26½x26½	30 x34	41 x45
Top, inside	10⅝x10⅝	13½x13⅝	16½x16¾	18¾x22½	24 x29⅛
Top, outside	17½x17⅝	20½x20½	21½x22	26¾x30¾	35 x40¼
Weight, lbs.	3,600	4,500	5,300	8,600	15,700

INGOTS.

The first set of ingots was used direct for chemical survey and etching of longitudinal sections, ingot numbers as follows: 12x12, IL4; 15x15,

FIG. 2—INGOTS AFTER SPLITTING.

IL5; 18x18, IL6; 20x24, IL7; 25x30, IL8. After pouring, they were switched around at intervals for about 20 minutes, and were then allowed to cool in the molds. Fig. 1 is a view of the ingots on their stools in the molds, showing a rather interesting assortment. In addition to the test ingots, the metal left in the ladle made another ingot of about 5,000 lbs. The dimensions and weights of the test ingots when cold are shown in table 6.

TABLE 6—INGOTS.

Ingot No.	IL4	IL5	IL6	IL7	IL8
Ingot size	12x12	15x15	18x18	20x24	25x30
Length	60 in.	59 in.	60 in.	59½ in.	58½ in.
Size, bottom	12x12	14⅞x14⅞	18 5/16 x18 5/16	19 9/16 x23⅝	24 13/16 x29 7/16
Size, top	10¼x10½	13¼x13 5/16	16¼x16 5/16	18½x22¼	23⅛x28⅛
Weight, lbs.	2,000	3,000	4,600	7,000	10,600

When cold, the ingots were split open (across the small diameter in the case of the oblong sections), by first slotting on opposite sides to a depth of four to six inches, with a tool about ¾ inch wide, and then splitting under the steam hammer by means of wedges. It might be stated that when broken these ingots gave off the odor of ammonia from the fracture, and also turned phenolphthalein paper red. The fractures, which showed up the pipes and blow holes nicely, are reproduced in Fig. 2, which shows the five ingots together. It will be noted that the "pipe" or shrinkage cavity goes deepest in the smallest ingot, and becomes less deep as the size of the ingot increases. The per cent. of the height of the ingot that the pipe extends downward from the top is very roughly as follows:

12x12 ingot	.....	80 per cent.
15x15 "	.....	75 "
18x18 "	.....	60 "
20x24 "	.....	40 "
25x30 "	.....	35 "

These figures refer simply to the shrinkage cavity and not to the blow holes.

One-half of each ingot was then planed down to below the fractured surface and finally finished by hand filing. These were then etched with a 10 per cent. water solution of copper ammonium chloride by leveling the surface of the ingot, pouring on the solution and allowing it to remain for several minutes. The surface was then washed off with a hose and scrub-brush, and then water containing a little ammonia poured over the surface to prevent a slight rust discoloration. The etched surface was then photographed at once while wet. It was hoped that the etching would show a "structure" corresponding to the distribution of the carbon, but this did not prove to be the case with the condition of the surface and method used. The photographs showed the cavaties and blow holes very nicely, however, and are reproduced in following figures:

Fig. 3. 12x12 ingot.
Fig. 4. 15x15 ingot.
Fig. 5. 18x18 ingot.
Fig. 6. 20x24 ingot, 20-inch diameter.
Fig. 7. 25x30 ingot, 25-inch diameter.

These figures represent surfaces below the axis of the ingot, and therefore the pipes do not show in them, but cavities and blow holes in

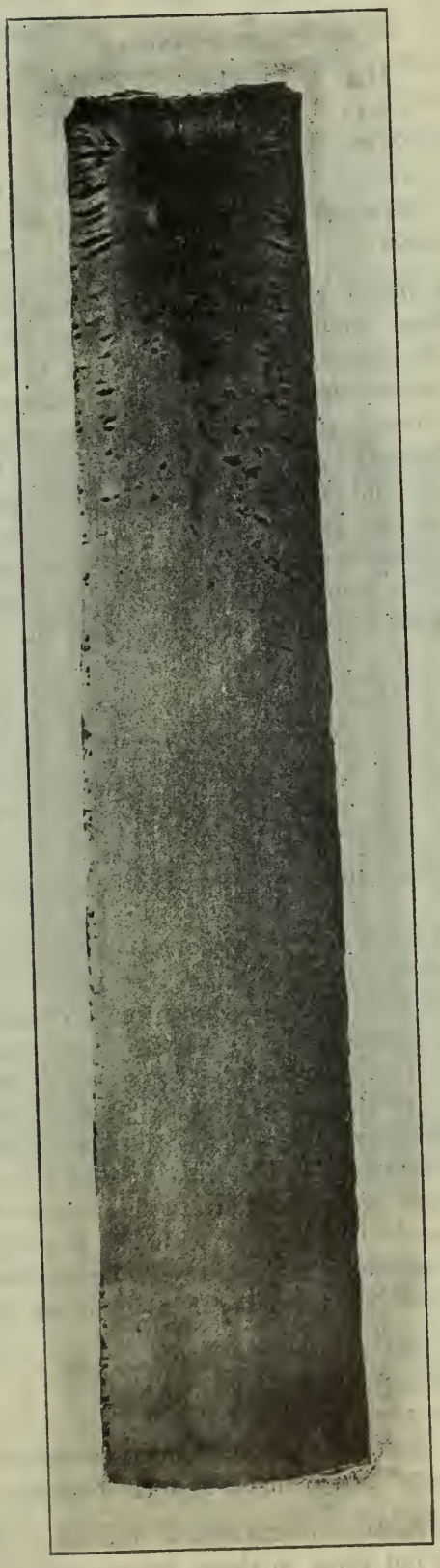


FIG. 3—ETCHED SECTION OF 12X12 INGOT.

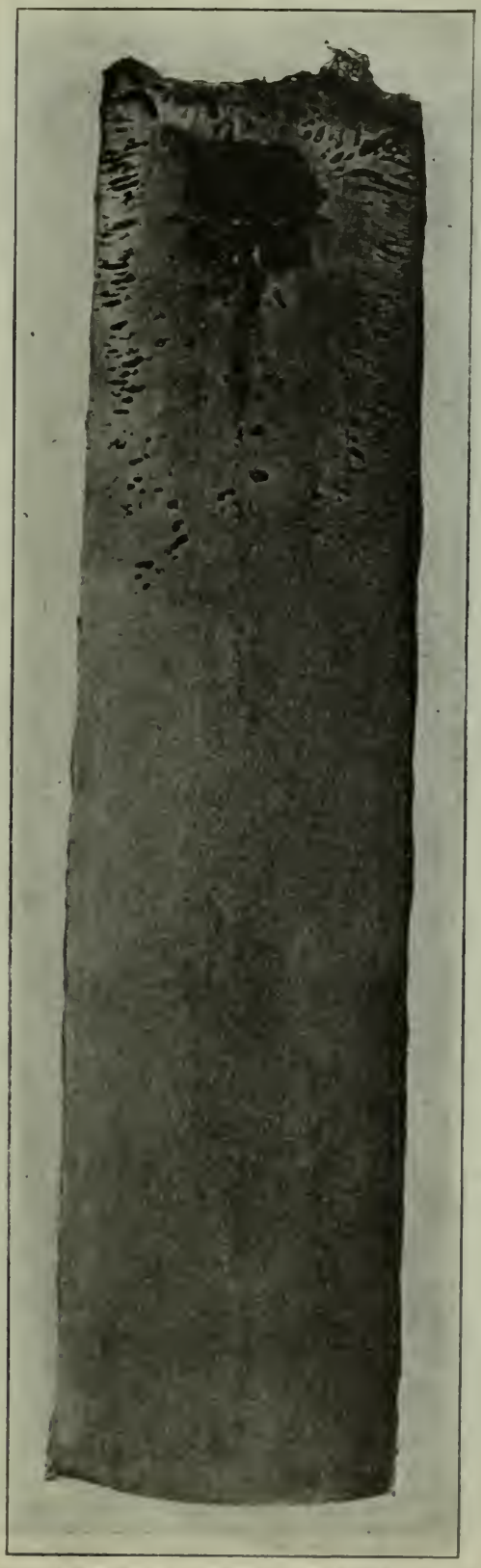


FIG. 4—ETCHED SECTION OF 15X15 INGOT.

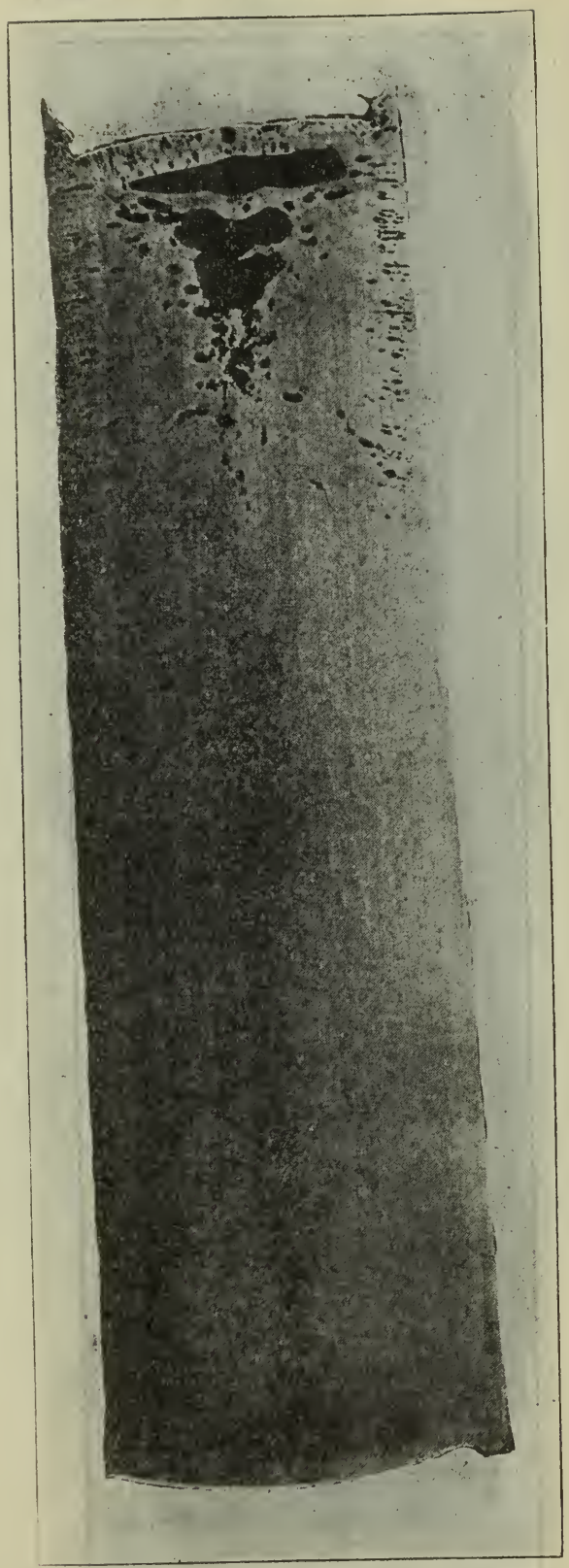


FIG. 5—ETCHED SECTION OF 18x18 INGOT.

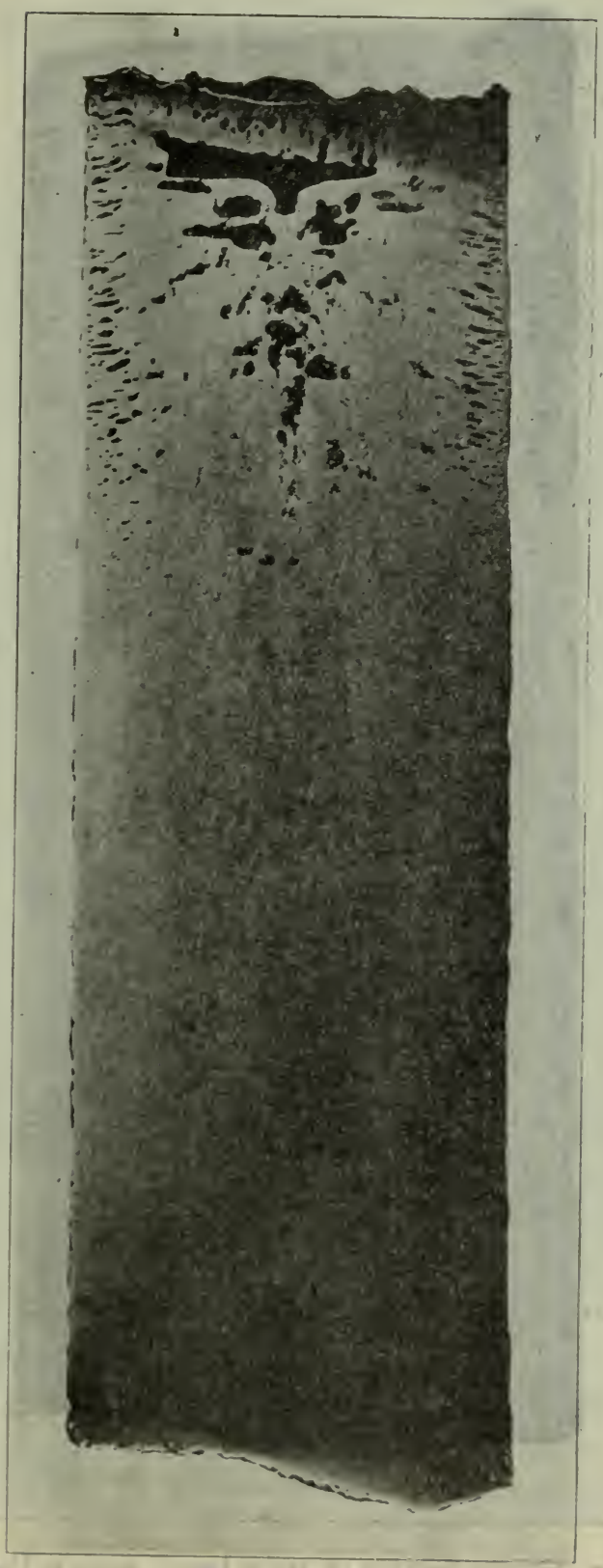


FIG. 6—ETCHED SECTION OF 20X24 INGOT, 20-INCH DIAMETER.

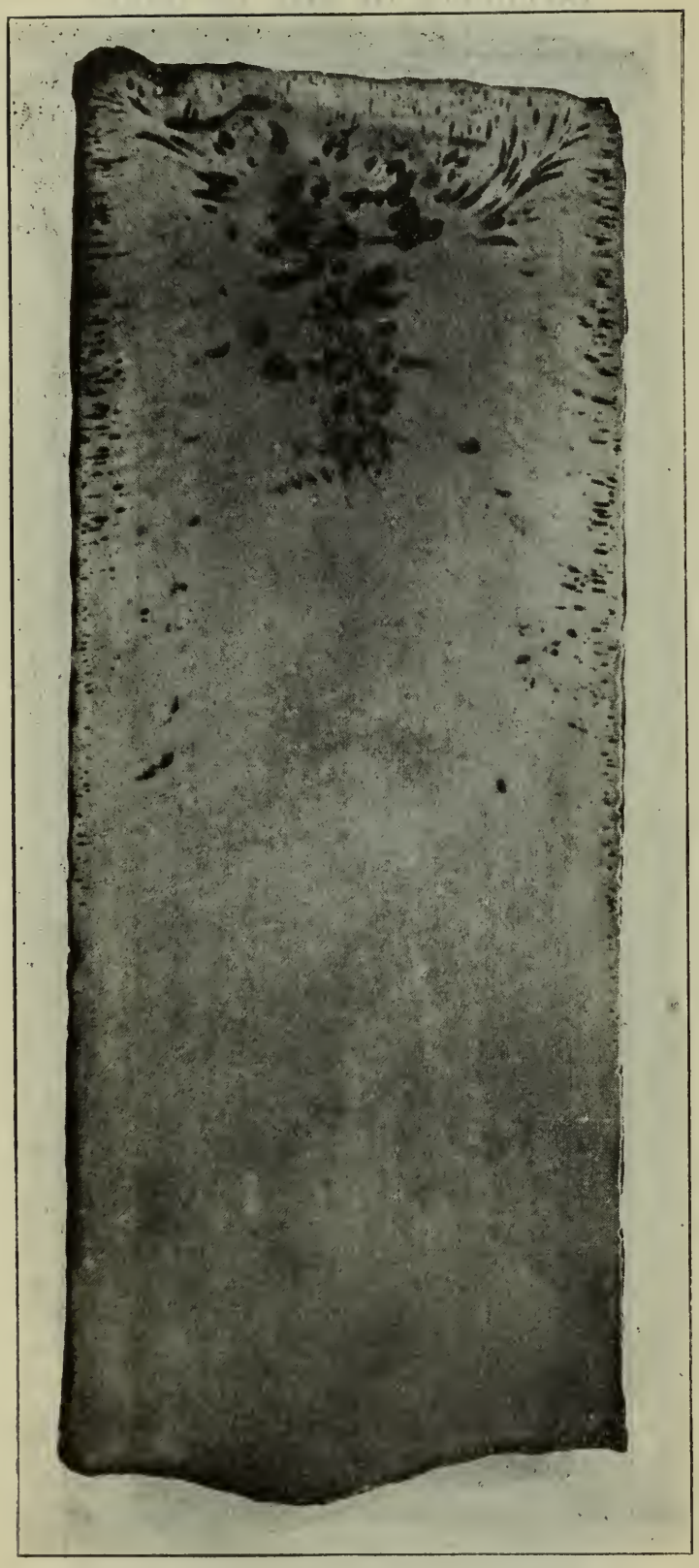


FIG. 7—ETCHED SECTION OF 25x30 INGOT, 25-INCH DIAMETER.

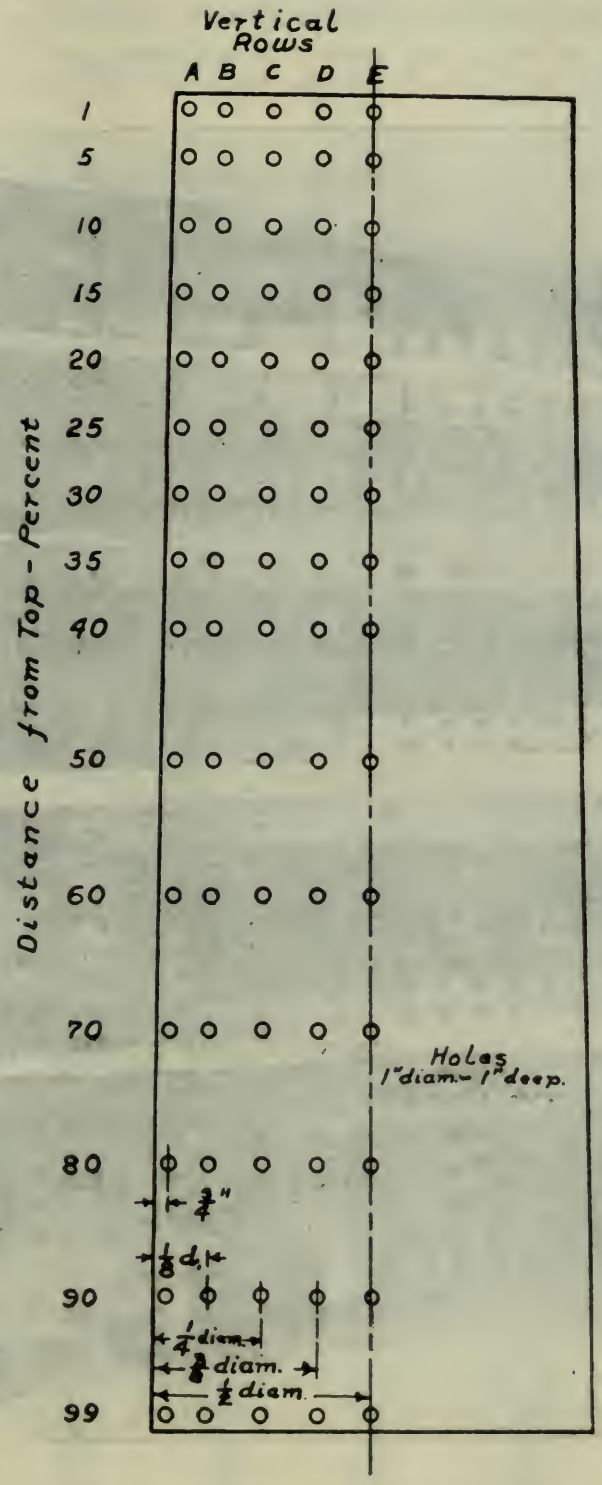


FIG. 8—DRILLING DIAGRAM FOR INGOTS.

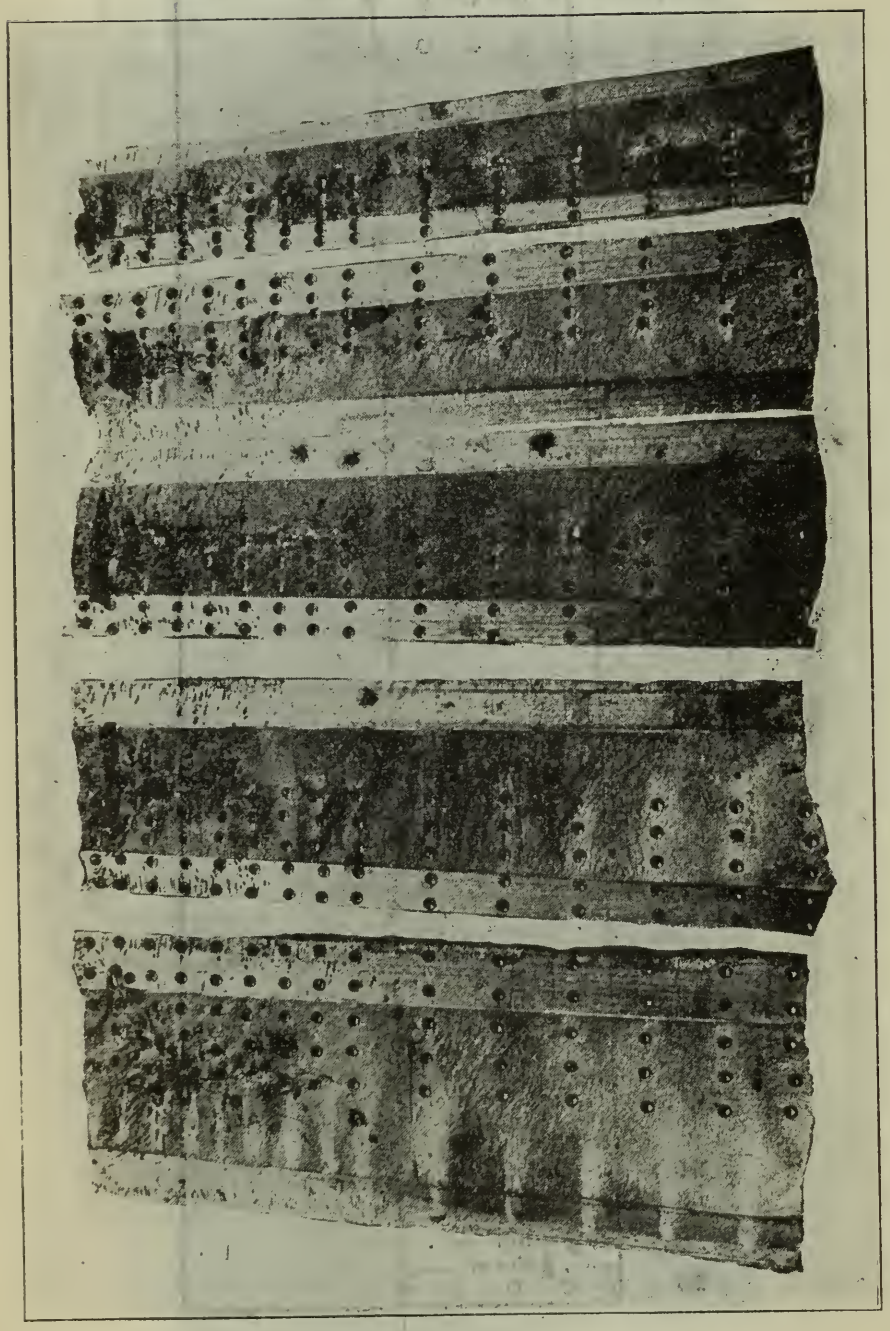


FIG. 9—INGOTS AFTER DRILLING FOR ANALYSIS.

the upper part of the ingot are well shown. The condition of "sponginess" extends downward about the same distance from the top in all the ingots, namely, about 30 per cent. The blow holes toward the axis of the ingot had a coating of slag appearing very much like a coat of varnish, while those near the walls of the ingot appeared to be free from such slag coating.

ANALYSES OF INGOTS.

One of the halves of each of the split ingots was used for making a chemical survey of the ingot, the drillings for analysis being taken as shown on the drilling diagram, Fig. 8. It will be noted that we obtained five vertical rows of drillings from one-half of the section, making a total of 75 samples, less the number of samples that could not be obtained, due to cavities in the ingot. The five ingots, after drilling, are shown together in Fig. 9. On each sample determinations were made of carbon (by combustion), phosphorus, sulphur, manganese and silicon, and the results are shown in tables as follows:

12x12 ingot, tables 7 to 11 inclusive.
15x15 ingot, tables 12 to 16 inclusive.
18x18 ingot, tables 17 to 21 inclusive.
20x24 ingot, tables 22 to 26 inclusive.
25x30 ingot, tables 27 to 31 inclusive.

TABLE 7—CARBON IN 12X12 INGOT.

Per Cent. from Top.	Vertical Row. A.	B.	C.	D.	E.
1	...	.48	.46	.49	.45
5	.48	.50	...	...	...
10	.50	.54	.67	.78	.82
15	.53	.57	.69	.77	.77
20	.53	.53	.64	.70	.71
25	.55	.56	.61	.67	.70
30	.57	.59	.58	.66	.69
35	.58	.60	.62	.62	.69
40	.58	.59	.59	.62	.60
50	.58	.60	.61	.60	.55
60	.61	.58	.61	.58	.60
70	.58	.59	.59	.58	.58
80	.60	.60	.59	.56	.56
90	.61	.61	.57	56	.56
99	.63	.62	.61	.61	.61

TABLE 8—PHOSPHORUS IN 12X12 INGOT.

Per Cent. from Top.	Vertical Row. A.	B.	C.	D.	E.
1	....	.068	.058	.066	.062
5	.063	.067	....	....	....
10	.067	.077	.116	.171	.188
15	.087	.084	.108	.169	.162
20	.082	.078	.097	.114	.157
25	.084	.080	.088	.116	.142
30	.092	.093	.094	.111	.116
35	.089	.099	.101	.102	.114
40	.094	.099	.100	.099	.101
50	.098	.099	.100	.099	.099
60	.092	.096	.100	.091	.094
70	.095	.096	.098	.086	.084
80	.096	.095	.098	.089	.085
90	.094	.096	.090	.089	.085
99	.092	.092	.093	.093	.093

TABLE 9—SULPHUR IN 12X12 INGOT.

Per Cent. from Top.	Vertical Row. A.	B.	C.	D.	E.
1	....	.023	.019	.023	.020
5	.020	.022	....	....	....
10	.022	.027	.041	.060	.070
15	.029	.026	.039	.059	.064
20	.032	.031	.037	.041	.058
25	.031	.032	.034	.042	.058
30	.034	.034	.032	.042	.044
35	.031	.032	.037	.038	.044
40	.032	.034	.037	.035	.039
50	.033	.034	.034	.033	.034
60	.033	.033	.035	.032	.033
70	.032	.034	.033	.031	.030
80	.032	.032	.034	.033	.033
90	.035	.037	.033	.029	.029
99	.031	.033	.033	.033	.033

TABLE 10—MANGANESE IN 12X12 INGOT.

Per Cent. from Top.	Vertical Row. A.	B.	C.	D.	E.
1	....	.95	.97	.98	.98
5	.97	.98	....	....	....
10	.96	.99	1.04	1.08	1.08
15	.98	.98	1.03	1.04	1.08
20	1.01	1.00	1.02	.99	1.04
25	1.02	1.00	1.02	1.03	1.00
30	1.02	1.02	1.01	1.03	1.01
35	.98	.98	1.00	1.01	1.01
40	.99	.99	.98	.99	1.00
50	1.00	.99	1.01	.99	.98
60	98	1.00	1.01	.97	.98
70	1.00	.98	.99	.99	.98
80	.98	1.00	1.01	.96	.98
90	.98	1.00	.97	1.00	.97
99	.98	.97	1.01	.98	.98

TABLE 11—SILICON IN 12X12 INGOT.

Per Cent. from Top.	Vertical Row. A.	B.	C.	D.	E.
1	....	.144	.144	.141	.141
5	.134	.141	....	....	....
10	.136	.137	.137	.140	.137
15	.134	.134	.139	.136	.143
20	.138	.136	.138	.143	.136
25	.136	.138	.133	.140	.141
30	.133	.136	.138	.136	.126
35	.135	.128	.135	.136	.131
40	.126	.128	.126	.126	.125
50	.131	.141	.137	.136	.133
60	.135	.126	.131	.123	.134
70	.124	.139	.131	.123	.128
80	.128	.132	.135	.133	.137
90	.130	.140	.134	.122	.127
99	.139	.133	.129	.125	.127

TABLE 12—CARBON IN 15X15 INGOT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.47	.44	.44	.52	.42
5	.39	.46	...	...	...
10	.39	.46	.64	...	...
15	.41	.48	.70	.78	.79
20	.43	.53	.65	.74	.82
25	.53	.50	.65	.66	.69
30	.55	.52	.56	.63	.71
35	.59	.54	.58	.58	.61
40	.55	.55	.59	.59	.69
50	.54	.56	.58	.55	.56
60	.55	.55	.58	.57	.56
70	.55	.55	.55	.54	.53
80	.54	.55	.53	.52	.51
90	.51	.53	.56	.50	.50
99	.54	.54	.55	.55	.57

TABLE 13—PHOSPHORUS IN 15X15 INGOT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.079	.065	.060	.084	.054
5	.054	.074	....	....	....
10	.055	.069	.121	....	....
15	.060	.074	.120	.165	.181
20	.080	.084	.124	.162	.198
25	.087	.075	.115	.130	.136
30	.094	.080	.092	.125	.148
35	.094	.089	.104	.106	.114
40	.094	.097	.109	.107	.135
50	.098	.099	.106	.096	.105
60	.098	.098	.103	.098	.090
70	.093	.095	.097	.091	.087
80	.094	.094	.094	.087	.086
90	.093	.096	.091	.084	.084
99	.091	.092	.092	.092	.092

TABLE 14—SULPHUR IN 15X15 INGOT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.026	.022	.021	.028	.020
5	.018	.026	....	....	....
10	.019	.025	.039	....	....
15	.019	.025	.050	.070	.076
20	.024	.025	.043	.060	.085
25	.038	.026	.040	.047	.056
30	.040	.029	.033	.046	.061
35	.034	.033	.033	.040	.045
40	.042	.042	.044	.041	.059
50	.039	.042	.045	.042	.041
60	.039	.041	.044	.042	.039
70	.033	.033	.032	.031	.030
80	.033	.032	.032	.032	.030
90	.034	.032	.038	.038	.036
99	.039	.041	.041	.039	.039

TABLE 15—MANGANESE IN 15X15 INGOT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	1.03	1.02	.99	.98	.98
5	1.00	.96	....	....	....
10	.97	.98	1.03	....	....
15	.94	.99	1.07	1.10	1.15
20	.99	.99	1.06	1.09	1.08
25	.99	1.00	1.01	1.07	1.07
30	.99	.99	1.01	1.05	1.07
35	.99	1.00	1.03	1.03	1.03
40	.98	1.00	1.00	1.00	1.04
50	.99	1.00	1.00	1.00	1.00
60	.98	.98	1.00	1.00	1.00
70	1.00	1.01	.99	.99	.98
80	1.00	1.00	1.00	.98	.98
90	.99	1.00	.98	.97	.97
99	.97	.97	.97	.97	.97

TABLE 16—SILICON IN 15x15 INGOT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.130	.150	.160	.145	.155
5	.128	.125	....	....	....
10	.134	.128	.134	....	....
15	.130	.130	.137	.137	.137
20	.130	.128	.129	.132	.136
25	.132	.124	.130	.126	.133
30	.124	.126	.130	.128	.125
35	.125	.122	.132	.133	.126
40	.128	.118	.112	.132	.128
50	.126	.117	.118	.122	.138
60	.113	.110	.122	.122	.112
70	.131	.127	.118	.123	.118
80	.124	.124	.118	.114	.119
90	.120	.122	.112	.118	.113
99	.114	.108	.120	.128	.124

TABLE 17—CARBON IN 18x18 INGOT.

Per Cent. from Top.	Vertical Row. A.	B.	C.	D.	E.
1	.47	.53	.46	.50	.50
5	.45	.47	.52	...	...
10	.47	.52	.58	.62	...
15	.46	.50	.57	.75	...
20	.48	.48	.59	.73	...
25	.52	.56	.61	.62	.80
30	.54	.56	.62	.62	.73
35	.55	.57	.62	.58	.61
40	.53	.57	.52	.54	.59
50	.54	.57	.50	.51	.54
60	.57	.54	.54	.52	.51
70	.51	.53	.52	.52	.50
80	.53	.55	.52	.48	.47
90	.54	.55	.49	.47	.45
99	.54	.55	.53	.52	.52

TABLE 18—PHOSPHORUS IN 18x18 INGOT.

Per Cent. from Top.	Vertical Row. A.	B.	C.	D.	E.
1	.064	.092	.067	.072	.069
5	.061	.069	.085	....	....
10	.059	.085	.104	.128	....
15	.067	.072	.098	.173	....
20	.086	.072	.102	.154	....
25	.082	.087	.108	.112	.192
30	.089	.091	.111	.112	.149
35	.094	.098	.113	.107	.126
40	.092	.100	.110	.101	.101
50	.096	.101	.105	.099	.096
60	.096	.099	.097	.096	.090
70	.095	.096	.091	.089	.082
80	.093	.097	.093	.084	.075
90	.097	.093	.084	.078	.077
99	.091	.093	.094	.092	.090

TABLE 19—SULPHUR IN 18x18 INGOT.

Per Cent. from Top.	Vertical Row. A.	B.	C.	D.	E.
1	.019	.031	.022	.025	.027
5	.019	.020	.028	....	....
10	.019	.024	.029	.040	....
15	.021	.022	.035	.060	....
20	.024	.025	.032	.058	....
25	.029	.030	.039	.040	.081
30	.033	.034	.041	.040	.063
35	.036	.036	.041	.040	.045
40	.028	.037	.040	.040	.040
50	.034	.039	.037	.039	.034
60	.029	.032	.033	.031	.028
70	.034	.031	.029	.030	.029
80	.034	.037	.034	.032	.030
90	.035	.035	.033	.028	.025
99	.034	.033	.035	.034	.034

TABLE 20—MANGANESE IN 18x18 INGOT.

Per Cent. from Top.	Vertical Row. A.	B.	C.	D.	E.
1	.90	.96	.98	.94	.96
5	.93	.92	.96	....	....
10	.92	.96	.97	.97	....
15	.94	.97	.99	1.04	....
20	.96	.93	1.00	1.04	....
25	.97	.98	1.00	1.01	1.09
30	.95	.96	.99	1.01	1.05
35	.99	1.00	1.00	1.01	1.01
40	.95	.97	.99	.97	.98
50	.96	.97	.97	.97	.98
60	.98	.98	.98	.97	.95
70	.98	.97	.98	.97	.97
80	1.03	1.03	1.02	1.00	.99
90	1.02	1.01	1.01	.98	.94
99	1.03	1.03	1.03	1.00	1.02

TABLE 21—SILICON IN 18x18 INGOT.

Per Cent. from Top.	Vertical Row. A.	B.	C.	D.	E.
1	.125	.142	.150	.124	.124
5	.125	.130	.128	....	....
10	.119	.127	.126	.123	....
15	.128	.140	.135	.151	....
20	.139	.133	.134	.148	....
25	.140	.136	.134	.137	.149
30	.129	.130	.128	.129	.128
35	.133	.128	.128	.126	.134
40	.140	.142	.138	.143	.141
50	.140	.138	.136	.134	.130
60	.138	.137	.136	.142	.137
70	.147	.144	.143	.130	.133
80	.142	.141	.136	.135	.141
90	.137	.134	.134	.142	.134
99	.137	.137	.129	.137	.138

TABLE 22—CARBON IN 20X24 INGOT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.40	.39	.48	.39	.41
5	.41	.46	...	...	...
10	.41	.51	.56	.59	...
15	.43	.51	.57	.77	...
20	.46	.47	.66	.78	...
25	.47	.52	.60	.63	.85
30	.54	.55	.59	.59	.71
35	.56	.54	.59	.59	.66
40	.55	.55	.60	.62	.65
50	.54	.56	.58	.55	.55
60	.56	.56	.58	.55	.53
70	.56	.56	.56	.52	.48
80	.54	.55	.53	.50	.47
90	.54	.55	.52	.50	.49
99	.55	.54	.55	.53	.54

TABLE 23—PHOSPHORUS IN 20X24 INGOT.

Per Cent. from Top.	A.	B.	C.	D.	E
1	.055	.050	.074	.050	.056
5	.051	.067	....	....	....
10	.054	.073	.085	.099	....
15	.058	.075	.085	.165	....
20	.064	.072	.093	.135	....
25	.071	.080	.094	.102	.199
30	.088	.096	.107	.099	.136
35	.090	.097	.109	.096	.149
40	.097	.098	.112	.104	.109
50	.094	.097	.104	.097	.088
60	.099	.097	.099	.092	.081
70	.095	.097	.096	.089	.080
80	.094	.099	092	.085	.078
90	.096	.098	.088	.085	.084
99	.094	.094	.093	.093	.094

TABLE 24—SULPHUR IN 20X24 INGOT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.018	.016	.030	.016	.017
5	.017	.023	....	....	....
10	.019	.024	.028	.034	....
15	.019	.025	.027	.065	....
20	.022	.026	.031	.055	....
25	.023	.028	.031	.041	.084
30	.031	.033	.037	.036	.061
35	.036	.037	.041	.035	.058
40	.034	.034	.039	.040	.045
50	.031	.035	.037	.034	.030
60	.033	.031	.034	.033	.032
70	.033	.035	.033	.032	.028
80	.032	.033	.033	.028	.027
90	.035	.036	.031	.027	.029
99	.031	.032	.033	.032	.032

TABLE 25—MANGANESE IN 20X24 INGOT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.92	.94	.97	1.00	.99
5	.90	.94	....	....	....
10	.92	.95	.99	1.00	....
15	.95	.98	1.00	1.10	....
20	.94	.97	.99	1.07	....
25	.96	1.00	1.03	1.04	1.10
30	.98	1.00	1.04	1.03	1.09
35	1.01	1.01	1.02	1.00	1.03
40	.99	1.00	1.09	1.02	1.02
50	1.02	1.00	1.01	.99	.97
60	.99	1.00	1.03	1.02	.98
70	.99	1.00	1.01	.95	.96
80	1.00	1.01	1.00	1.01	.97
90	1.00	1.00	1.00	1.00	1.01
99	.99	.99	.99	1.01	1.02

TABLE 26—SILICON IN 20X24 INGOT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.120	.137	.133	.152	.129
5	.122	.124	....	....	....
10	.128	.130	.130	.140	....
15	.124	.123	.124	.130	....
20	.123	.135	.134	.142	....
25	.125	.121	.126	.133	.134
30	.130	.127	.137	.128	.133
35	.134	.137	.134	.130	.135
40	.133	.131	.133	.130	.128
50	.128	.133	.131	.133	.127
60	.129	.133	.130	.135	.124
70	.132	.128	.125	.129	.129
80	.130	.138	.130	.132	.130
90	.132	.134	.136	.129	.130
99	.129	.132	.132	.134	.132

TABLE 27—CARBON IN 25X30 INGOT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.47	.40	.46	.48	.49
5	.42	.37	.41	.59	.61
10	.39	.45	.60	....	.62
15	.42	.47	.66	.88	1.04
20	.42	.49	.66	1.00	1.18
25	.46	.51	.76	.85	.88
30	.46	.50	.66	.69	.77
35	.47	.56	.65	.68	.77
40	.53	.56	.62	.64	.70
50	.51	.54	.60	.55	.52
60	.52	.57	.54	.54	.49
70	.55	.56	.55	.51	.46
80	.54	.54	.49	.46	.45
90	.53	.53	.48	.48	.48
99	.54	.54	.54	.55	.54

TABLE 28—PHOSPHORUS IN 25X30 INGOT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.074	.062	.066	.086	.083
5	.052	.064	.066	.108	.116
10	.052	.064	.110	....	.110
15	.053	.072	.121	.205	.295
20	.065	.072	.110	.265	.302
25	.062	.077	.128	.174	.199
30	.072	.078	.120	.142	.174
35	.070	.083	.121	.132	.176
40	.087	.080	.117	.122	.134
50	.089	.088	.106	.101	.095
60	.094	.100	.096	.094	.082
70	.095	.100	.100	.089	.080
80	.094	.102	.085	.076	.072
90	.094	.095	.085	.082	.083
99	.093	.096	.095	.095	.095

TABLE 29—SULPHUR IN 25X30 INGOT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.027	.022	.022	.027	.030
5	.017	.020	.022	.039	.039
10	.013	.020	.035	....	.040
15	.020	.024	.041	.084	.124
20	.023	.026	.043	.110	.164
25	.029	.032	.055	.072	.083
30	.027	.027	.043	.053	.068
35	.027	.031	.043	.047	.072
40	.031	.029	.044	.048	.058
50	.031	.030	.041	.039	.035
60	.035	.038	.036	.037	.031
70	.032	.040	.044	.032	.027
80	.034	.043	.032	.038	.026
90	.036	.036	.030	.029	.031
99	.035	.032	.037	.037	.041

TABLE 30—MANGANESE IN 25X30 INGOT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.91	.94	.95	.95	.96
5	.92	.92	.92	1.01	1.02
10	.91	.94	1.03	....	1.04
15	.92	.94	1.00	1.18	1.24
20	.95	.96	1.01	1.19	1.26
25	.95	.96	1.05	1.12	1.15
30	.95	.96	1.06	1.08	1.10
35	.95	.96	1.03	1.04	1.07
40	.97	.96	1.03	1.04	1.03
50	.98	.98	.99	.98	.98
60	.98	.98	.98	.97	.96
70	.98	.99	.99	.98	.98
80	.98	.99	.98	.97	.97
90	.98	.98	.96	.96	.96
99	.98	.98	.98	.97	.98

TABLE 31—SILICON IN 25X30 INGOT.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.116	.150	.136	.123	.128
5	.122	.122	.125	.132	.134
10	.127	.139	.131	....	.137
15	.130	.122	.143	.144	.152
20	.132	.133	.140	.158	.150
25	.120	.126	.140	.139	.137
30	.133	.133	.139	.141	.144
35	.136	.136	.139	.144	.147
40	.139	.136	.135	.138	.144
50	.138	.130	.138	.136	.135
60	.130	.136	.138	.136	.136
70	.130	.130	.134	.133	.130
80	.127	.130	.130	.130	.128
90	.128	.131	.135	.137	.139
99	.132	.132	.132	.134	.130

Probably the five samples from the bottom of the ingot represent pretty well the average steel in the ingot, and the average results are shown in table 32.

TABLE 32—AVERAGES OF SAMPLES 99A-B-C-D AND E.

Ingot.	C.	P.	S.	Mn.	Si.
12x12	(.616)	.0926	.0326	.984	.131
15x15	.552	.0918	.0398	.970	.119
18x18	.532	.0920	.0340	1.022	.136
20x24	.542	.0936	.0320	1.000	.132
25x30	.542	.0948	.0364	.978	.132
Average	.54	.093	.035	.99	.130

The general average of each element shown in the table can probably be taken as representing the heat. The carbon in the 12x12 ingot shows .616 per cent., which is considerably higher than in the other ingots, namely, .542 per cent., and it has been omitted in obtaining the general average, although it can probably be taken as correct for the 12x12 ingot, as the determinations were thoroughly checked.

A study of the analyses shows that in general the extreme variations in composition at any given distance from the top of the ingot are shown by the axis and the walls of the ingot, in the upper part of the ingot the axis showing considerably higher carbon, phosphorus and sulphur than the walls, while in the lower part of the ingot the axis shows lower amounts of these elements. Manganese also shows a similar separation, but to a much smaller extent. Silicon remains fairly evenly distributed throughout the ingot. In order to show conveniently the changes of composition from the top to the bottom of the ingot, I give in Figs. 10 to 14, inclusive, carbon, phosphorus and sulphur diagrams for the five ingots. The distance from the top of the ingot, in per cent., is plotted horizontally, and the amount of the element vertically, and both the axis and the wall are represented. These diagrams show some very interesting results, and should be studied closely. The average carbon, phosphorus and sulphur in the heat, as deduced above, are shown on the diagrams, and it will be noticed that the axis shows very strong segregation of the carbon, phosphorus and sulphur in the upper part of the ingot, while in the lower part of the ingot these elements go somewhat below the average amount, or show "negative" segregation. Close to the top the axis shows negative segregation also. The wall of the ingot shows negative segregation in the upper third, and about the average composition in the lower half of the ingot. The maximum carbon found in the axis, the minimum in the axis in the lower half of the ingot, and the minimum amount found in the wall, are shown for the several ingots in table 33.

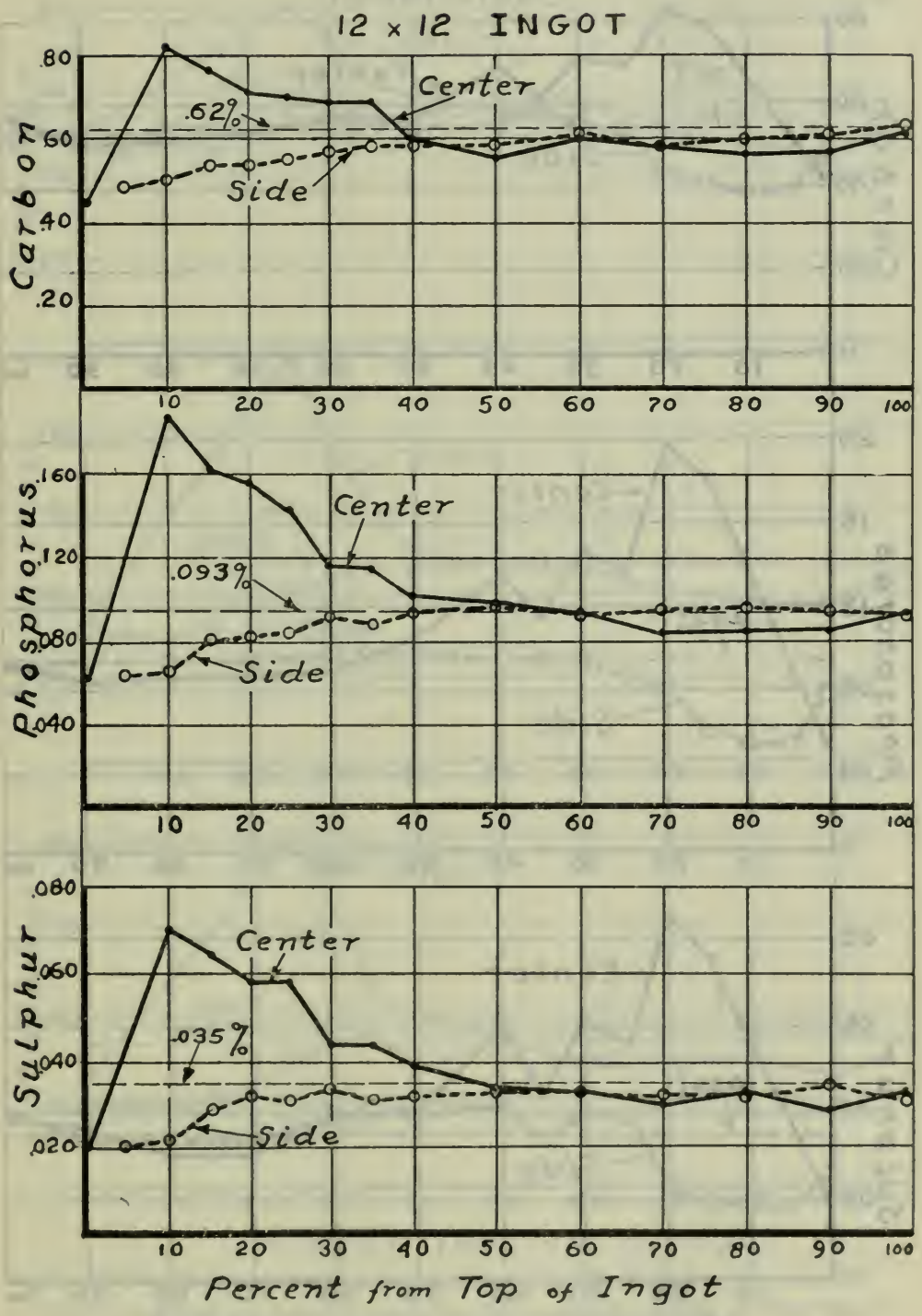


FIG. 10—CARBON, PHOSPHORUS AND SULPHUR DIAGRAMS OF THE 12X12 INGOT.

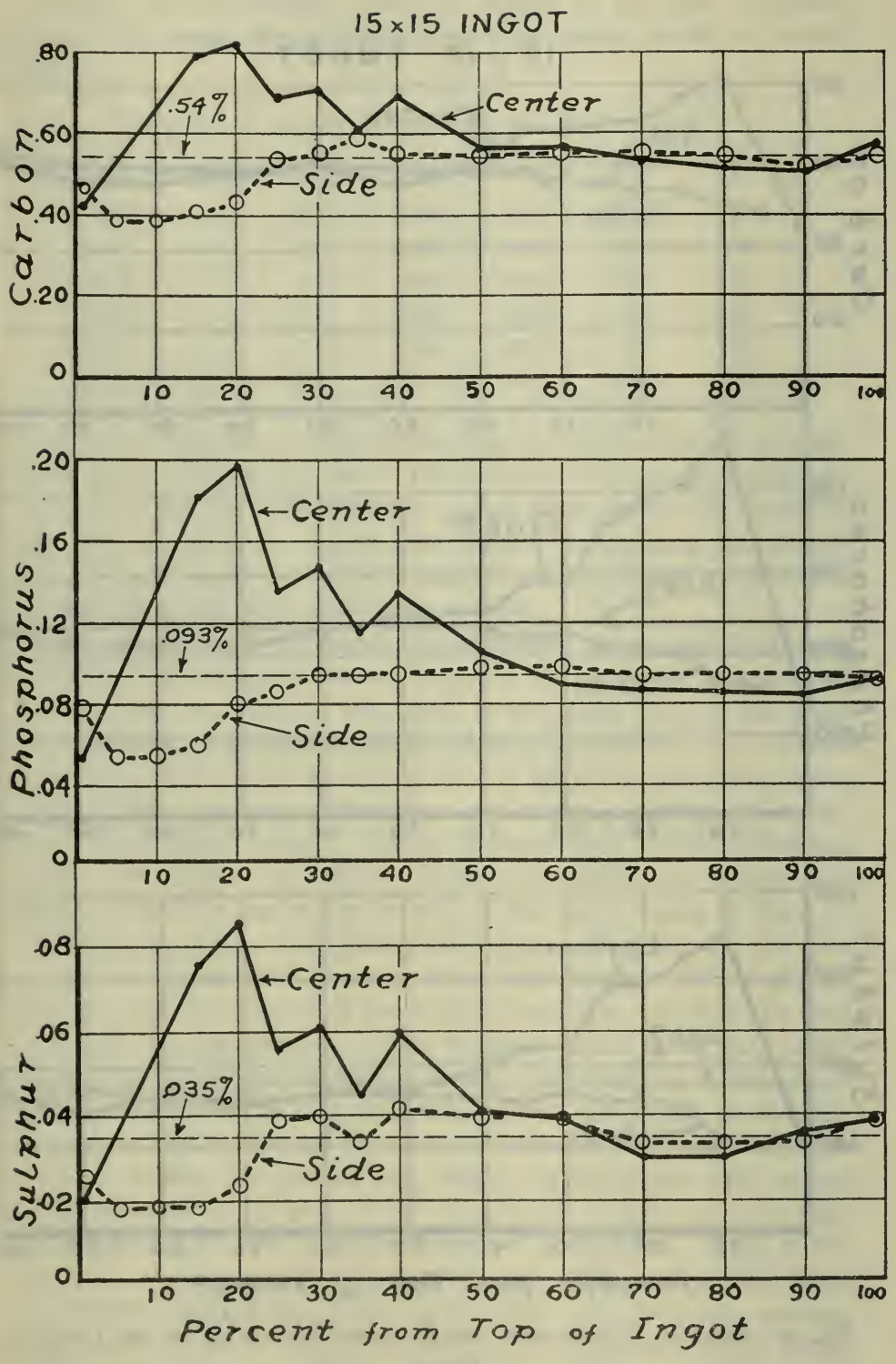


FIG. 11—CARBON, PHOSPHORUS AND SULPHUR DIAGRAMS OF THE 15X15 INGOT.

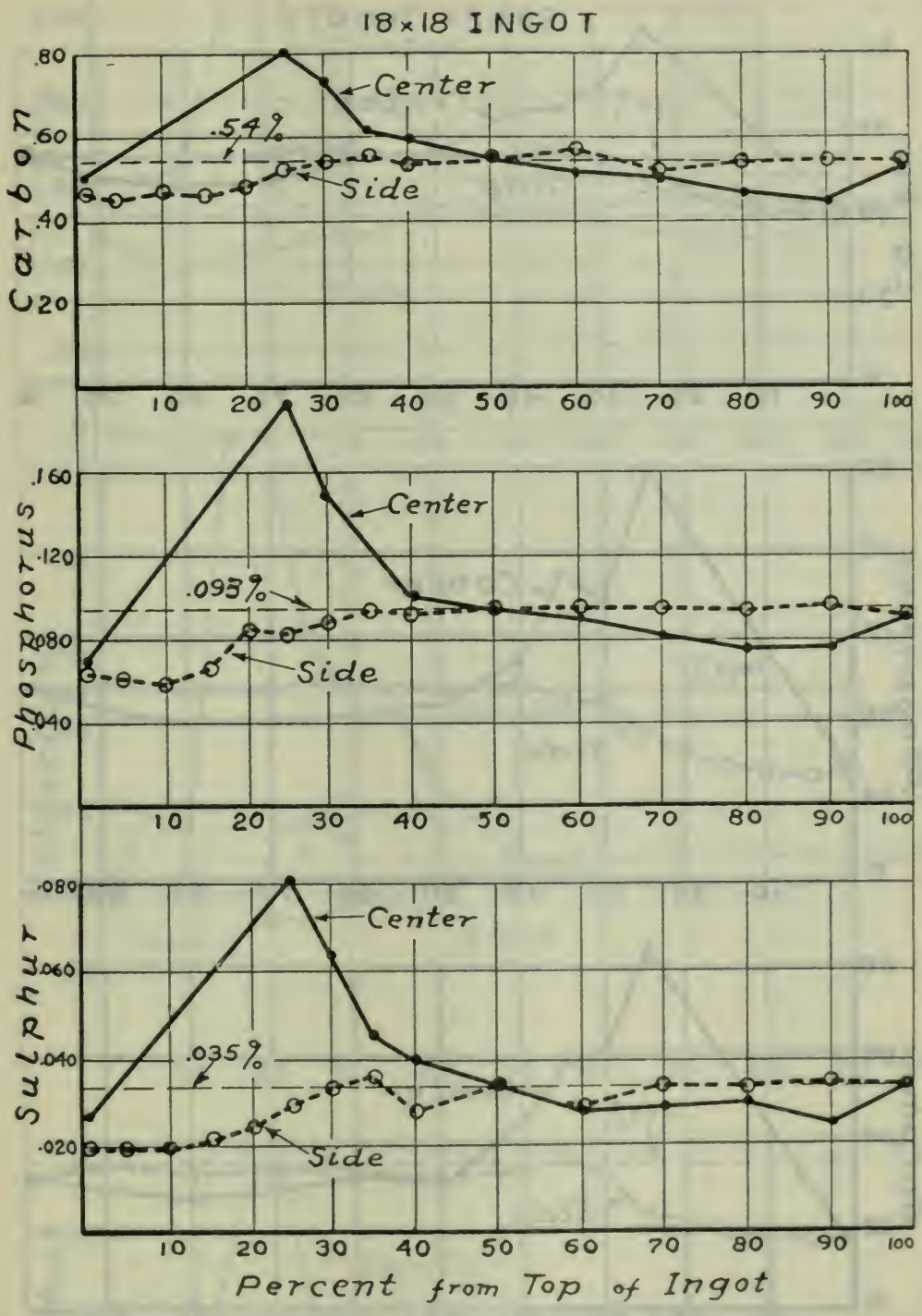


FIG. 12—CARBON, PHOSPHORUS AND SULPHUR DIAGRAMS OF THE 18x18 INGOT.

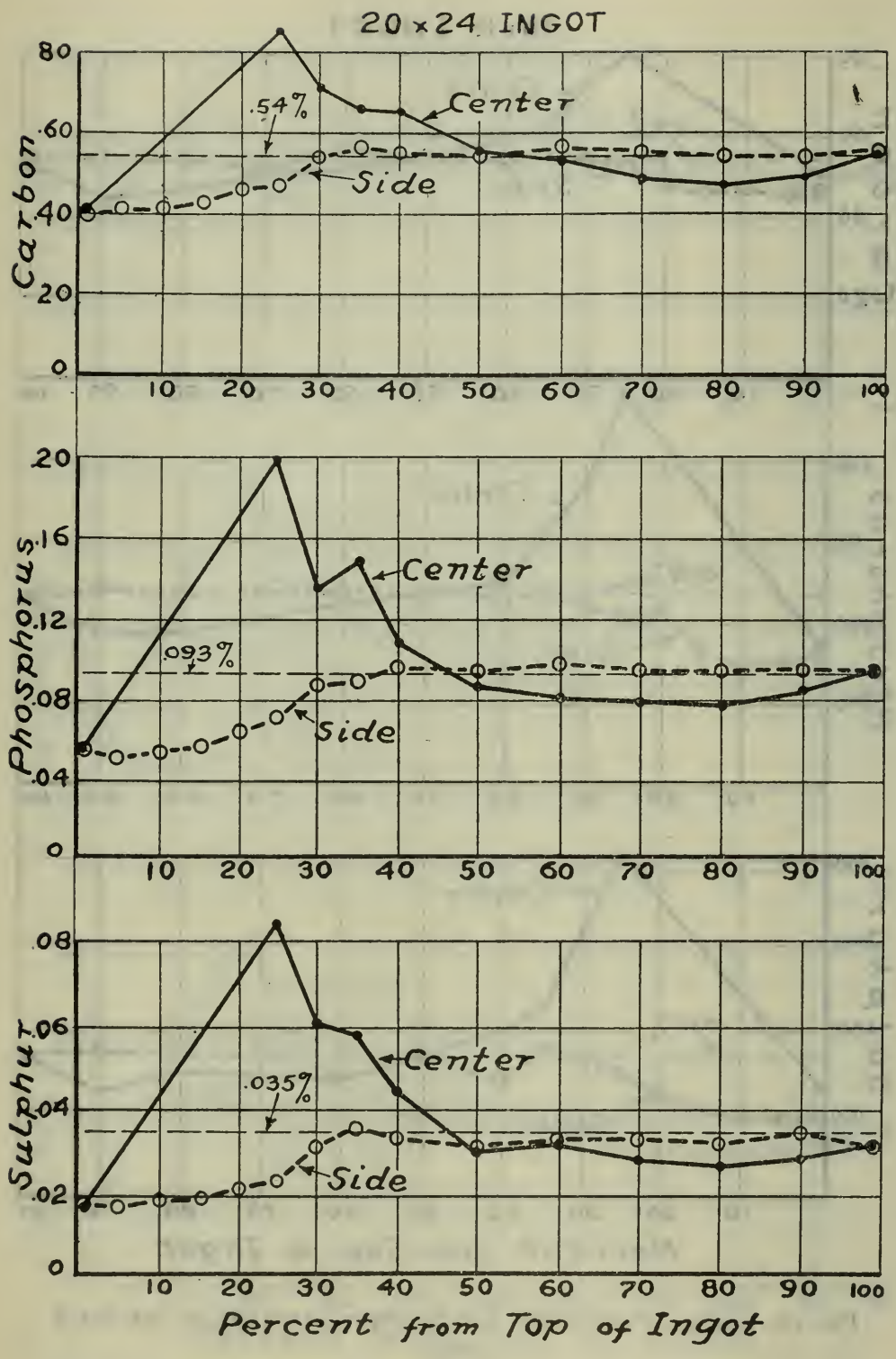


FIG. 13—CARBON, PHOSPHORUS AND SULPHUR DIAGRAMS OF THE 20X24 INGOT.

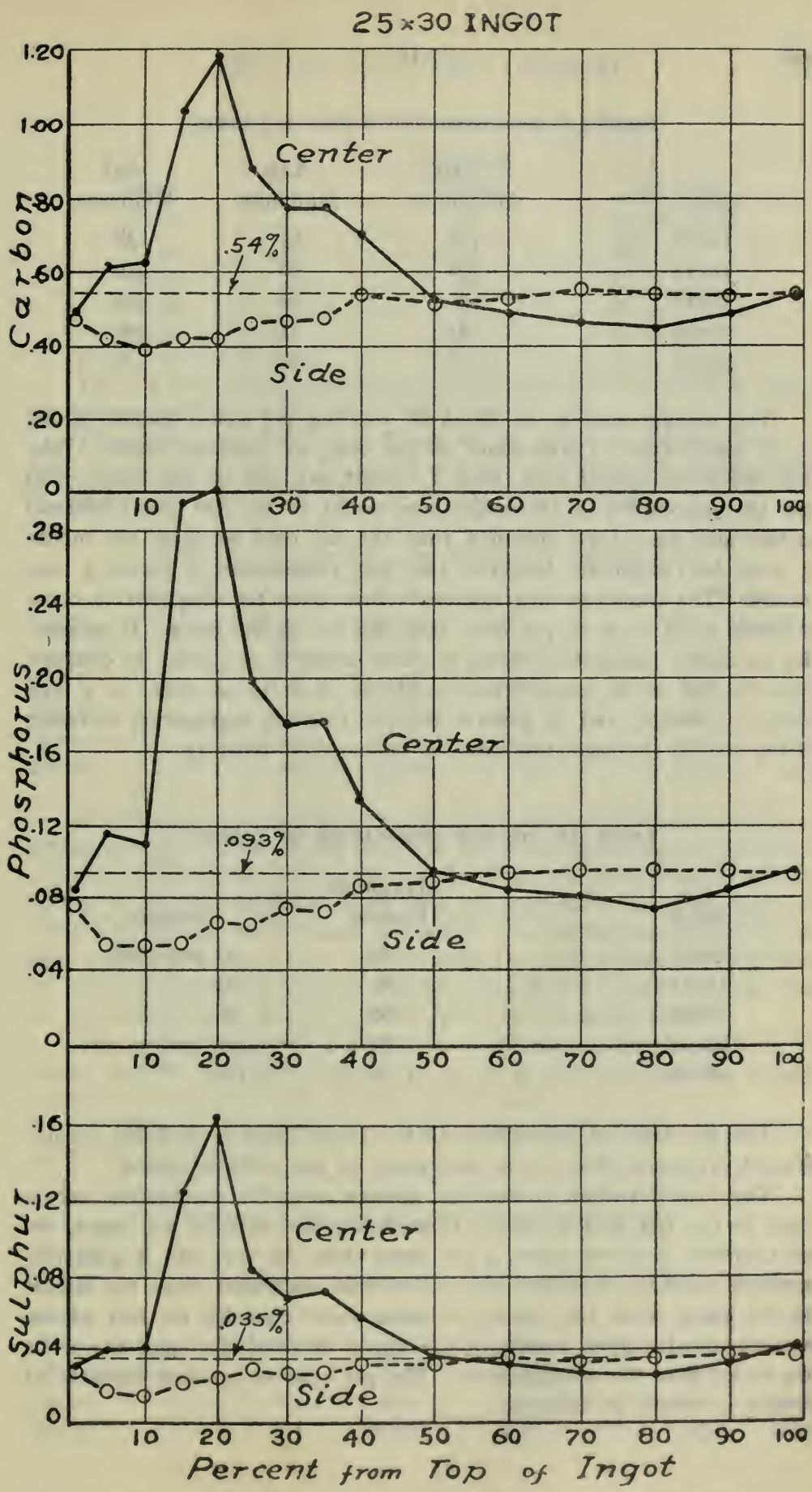


FIG. 14—CARBON, PHOSPHORUS AND SULPHUR DIAGRAMS OF THE 25X30 INGOT.

TABLE 33—MAXIMUM AND MINIMUM CARBON.

Ingot.	Axis Maximum.	Axis Minimum.	Wall Minimum.
12x12	.82	.55	.48
15x15	.82	.50	.39
18x18	.80	.45	.45
20x24	.85	.47	.40
25x30	1.18	.45	.39

The average carbon in the heat was .54 per cent., except in the 12x12 ingot, where it was about .62 per cent., as explained above. Why this difference should have been I cannot say, but of the causes that can be conjectured, a reasonable one seems to be that the additional carbon may have been absorbed from the tar used to spray the molds. It must be recognized, however, that this explanation is purely a conjecture. The maximum segregation is seen from the diagrams to occur at about 10 to 20 or 25 per cent. from the top of the ingot. In general, the maximum segregation seems to occur about 20 per cent., by distance, from the top of the ingot, which would be about 15 per cent., or a little more, by weight, and in general the per cent. of segregation increases as the size of the ingot increases, as indicated by table 34.

TABLE 34—POSITIVE SEGREGATION OF CARBON.

Ingot.	Maximum Carbon.	Increase.
12x12	.82	32 per cent.
15x15	.82	52 "
18x18	.80	48 "
20x24	.85	57 "
25x30	1.18	119 "

The per cent. of segregation in the 12x12 ingot is probably greater than shown above, due to the uncertainty of the average carbon.

The lowest carbon content or greatest negative segregation occurs close to the top of the ingot. Considering the walls of the ingot, the least carbon is found about 5 per cent. from the top, and it gradually increases until the average carbon is reached, somewhat above the middle of the ingot, when the amount remains about constant the rest of the way down. In other words, in the upper third of the ingot the walls are softer than the average steel. The per cent. of greatest decrease of carbon is shown in table 35.

TABLE 35—NEGATIVE SEGREGATION OF CARBON.

Ingot.	Minimum Carbon.	Decrease.
12x12	.48	23 per cent.
15x15	.39	28 "
18x18	.45	17 "
20x24	.40	26 "
25x30	.39	28 "

The per cent. of the maximum decrease, as shown in this table, seems to bear no relation to the size of the ingot.

The maximum phosphorus found in the axis, the minimum in the axis in the lower half of the ingot, and the minimum phosphorus found in the wall, are shown in table 36 for the several ingots.

TABLE 36—MAXIMUM AND MINIMUM PHOSPHORUS.

	Axis.			Wall.	
Ingot.	Max.	Increase.	Min.	Min.	Decrease.
12x12	.188	102%	.084	.063	32%
15x15	.198	113%	.084	.054	42%
18x18	.192	106%	.075	.059	36%
20x24	.199	114%	.078	.051	45%
25x30	.302	225%	.072	.052	44%

No samples for analysis were taken from the axis between 1 per cent. and 25 per cent. from the top from the 18x18 and 20x24 ingots, account of cavities or sponginess, but a study of the diagrams in connection with the results in table 36 seems to show that the segregation of phosphorus increases as the size of the ingot increases. The average phosphorus in the heat was about .093 per cent., and the maximum segregation of phosphorus, or increase above the average amount, ranged from about 100 per cent. in the 12x12 ingot, to over 200 per cent. in the 25x30 ingot.

The greatest negative segregation of phosphorus in the wall of the upper third of the ingot ranged from 32 to 45 per cent., showing a slight tendency to increase with the size of the ingot.

In table 37, the results for sulphur are given similar to the ones given for phosphorus.

TABLE 37—MAXIMUM AND MINIMUM SULPHUR.

	Axis.			Wall.	
Ingot.	Max.	Increase.	Min.	Min.	Decrease.
12x12	.070	100%	.029	.020	43%
15x15	.085	143%	.030	.018	49%
18x18	.081	131%	.028	.019	46%
20x24	.084	140%	.027	.017	51%
25x30	.164	369%	.026	.013	63%

The average sulphur in the heat was .035 per cent., and the maximum segregation ranged from 100 per cent. in the 12x12 ingot, to 369 per cent. in the 25x30 ingot. The greatest negative segregation of sulphur in the wall of the ingot ranged from 43 per cent. to 63 per cent., increasing in general somewhat with the size of the ingot.

From the above discussion and the diagrams, it will be noted that the greatest segregation occurred with the sulphur, the next in percentage with the phosphorus, and carbon ranked third in per cent. of segregation. Another point of interest is that the various elements segregate together, that is, the concentrations occur in the same areas, although the percentages differ for the different elements.

In order to show more clearly than the tables the separation of the elements into areas of different concentrations, Fig. 15 is given, showing the distribution of phosphorus throughout the ingot for each of the five different ingots. These diagrams show regions of six different concentrations of phosphorus, as follows:

A—Below .070 per cent.
B—.070 to .085 per cent.
C—.085 to .105 per cent.
D—.105 to .135 per cent.
E—.135 to .175 per cent.
F—Above .175 per cent.

The same diagrams would represent regions of different concentrations of carbon and of sulphur, but phosphorus was selected for this purpose, as it seems to have been very uniform throughout the heat before pouring, while the average carbon in the 12x12 ingot seems to have been materially higher than in the other ingots, and the sulphur seems to show some variations, although of considerably less importance.

The amounts of carbon and sulphur represented by the above regions would be about as follows:

	Carbon.	Sulphur.
A	Below .47 per cent.	Below .024 per cent.
B	.47 to .51 " "	.024 to .030 " "
C	.51 to .57 " "	.030 to .042 " "
D	.57 to .66 " "	.042 to .055 " "
E	.66 to .77 " "	.055 to .070 " "
F	Above .77 " "	Above .070 " "

The area of maximum concentration indicated by F, and for which the minimum limit of .175 per cent. phosphorus has been chosen, is seen to lie in the upper part of the ingot, and also to extend lower down into the ingot as the size of the ingot increases. The middle of this region extends from about 10 per cent. of the length from the top of the 12x12 ingot, to a little over 20 per cent. from the top in the 25x30 ingot. By weight the amounts would be several per cent. less. Area C represents steel of average composition, while B represents steel with negative segregation. All the ingots show some of the B area in the lower part of the ingot, but its proportionate amount increases in general

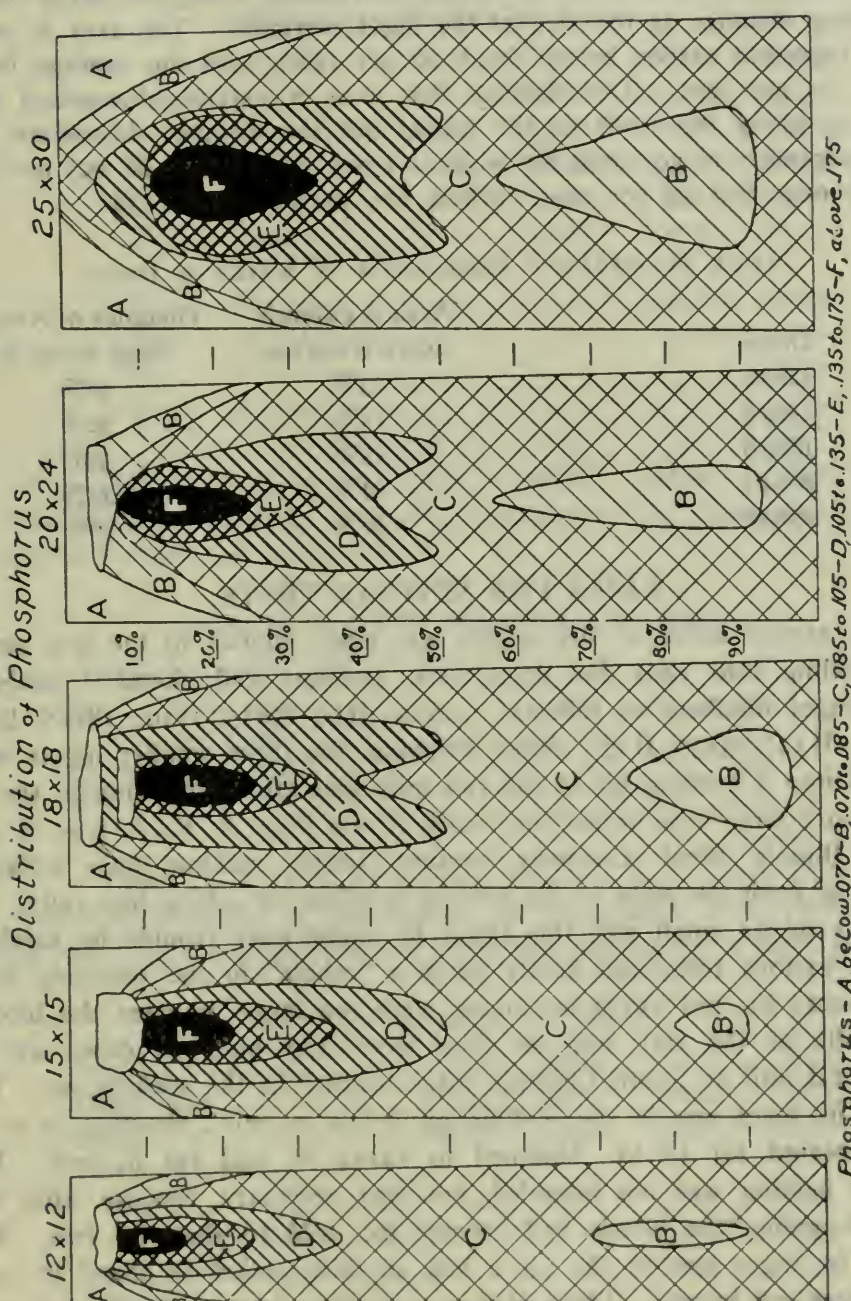


FIG. 15—DISTRIBUTION OF PHOSPHORUS IN THE SEVERAL INGOTS.

as the size of the ingot increases. The greatest negative segregation is seen in area A at the top of the ingot, which contains less than .070 per cent. phosphorus. This area includes the walls of the upper part of the ingot, and is seen to extend downward along the walls an increasing distance as the size of the ingot increases. The area A would also represent carbon below about .47 per cent., with the average in the steel .54 per cent. The distance that area A extends downward from the top along the walls of the ingot, and the distance downward that it is necessary to go along the walls to reach the average of .093 per cent. phosphorus and .54 per cent. carbon, are shown in table 38.

TABLE 38—NEGATIVE SEGREGATION IN WALLS OF INGOT.

Ingot	Area A extends down from top.	Distance of Average Steel from top.
12x12	13%	30%
15x15	15%	30%
18x18	15%	35%
20x24	24%	35%
25x30	30%	50%

RAILS FOR SPECIAL TESTS.

A second series of five ingots was made similar to the first series, for rolling into rails for drop tests, etchings and chemical analyses, with ingot numbers as follows: 12x12, Il 9; 15x15, Il 10; 18x18, Il 11; 20x24, Il 12; 25x30, Il 13. After stripping, the three smaller ingots were placed into a soaking pit at the rail mill, and after remaining in the pit for two hours, were rolled into rails of 100 lbs. A. R. A.-type B section, Illinois Steel Company section 10030, making only sufficient cropping from the ends of the blooms to allow of rolling into rails. On account of its small size the 12x12 in. ingot gave trouble by catching in the various rolls, and finally made a "cobble" in the roughing rolls. The 20x24 in. and 25x30 in. ingots were too large to enter the blooming rolls of the rail mill, so they were first bloomed down at the structural mill at South Chicago, after heating in the soaking pit. The 20x24 in. ingot was in the soaking pit 2 hrs. 20 min., bloomed to 16x16 in., reheated for ½ hr., bloomed to 14x14 in. and cut in two. The second heating was not intended, but was necessary, because, after the first blooming, the bloom had become too cold to shear in two. The 25x30 in. ingot was in the pit 2 hrs. 40 min., rolled to 16x16 in., and the bloom cut in two. These blooms were then brought to the rail mill, put into the soaking pit for 3 hrs., and rolled into rails as above. The two parts from the 25x30 in. ingot were each cut in two, after blooming to about 8x8 in., as the rail bar would otherwise have been too long for the runways. The rail bars of the 15x15 and 18x18 ingots were each rolled in one piece, the 20x24 ingot in two pieces, and the 25x30 ingot in

four pieces. There were no croppings from any of the rail bars, except from the 25x30 ingot.

The weights of the individual rails are shown in table 39.

TABLE 39—WEIGHTS OF RAILS.

Ingot number	Il 10	Il 11	Il 12	Il 13
Ingot size	15x15	18x18	20x24	25x30
Rail A	1,085	1,100	1,076	1,107
B	1,109	1,128	1,095	1,102
C	660	1,120	990	1,114
D	.....	1,000	1,075	1,115
E	.....	.....	1,098	1,080
F	.....	.....	936	1,100
G	.....	.....	.....	1,097
H	.....	.....	.....	1,110
Total	2,854	4,348	6,270	8,825

The several croppings from the rail bar of the 25x30 ingot were as shown in table 40.

TABLE 40—CROPPINGS FROM 25X30 RAIL BAR.

A rail, top end	44	lbs.
B " back end	120	"
C " top end	75	"
D " back end	260	"
F " back end	296	"
Total	795	lbs.

The total weights of the ingots, as determined from the weights of the rails, and the bloom and rail croppings, are shown in table 41.

TABLE 41—WEIGHTS OF INGOTS.

Ingot number	Il 10	Il 11	Il 12	Il 13
Ingot size	15x15	18x18	20x24	25x30
Rails	2,854	4,348	6,270	8,825
Bloom Crops—				
Top	97	115	118	218
1st intermediate	.....	.....	125	115
2nd intermediate	.....	.....	113	109
Bottom	103	78	115	130
Rail crops	.....	.....	.....	795
Total	3,054	4,541	6,741	10,192

The lengths of the full-length rails were measured, and are shown in table 42.

TABLE 42—LENGTH OF RAILS.

Ingot number	Il 10	Il 11	Il 12	Il 13
Ingot size	15x15	18x18	20x24	25x30
Rail A	.....	.....	.....	33′ 0¼″
B	33′ 0″	33′ 0¼″	32′ 11¾″	32 11⅞
C	.....	33 0⅛	.....	33 0⅜
D	.....	.....	.....	33 0¼
E	.....	.....	32 11¾	.....
F	.....	.....	.....	32 11⅝
G	.....	.....	.....	.....
H	.....	.....	.....	33 0

The saws are usually set for this section for a shrinkage of 6¾ in., and this was the allowance in this case, although I did not measure the saw setting at the time these rails were rolled.

The various rails in this series were divided into units of one-third rail, or 11 ft. each, for drop tests, analyses and etchings. From each unit 1 ft. was cut for etching and analysis, then 5 ft. for drop test with the head in tension, and the other 5 ft. for drop test with the base in tension. The pieces from each rail were given numbers as follows:

No. 1. 1 ft. Analysis and etching.
2. 5 ft. Drop test, head tension.
3. 5 ft. Drop test, base tension.
4. 1 ft. Analysis and etching.
5. 5 ft. Drop test, head tension.
6. 5 ft. Drop test, base tension.
7. 1 ft. Analysis and etching.
8. 5 ft. Drop test, head tension.
9. 5 ft. Drop test, base tension.

The distance of each test piece from the top of the ingot, expressed in lbs., is shown in tables 43 to 46, inclusive. The samples for analysis, and the section for etching, were taken from the lower end of the 1-ft. piece, and the distances are shown to the lower end of the piece, but the 5-ft. pieces were struck in the drop test at the middle of the piece, and the distances are calculated to the middle.

TABLE 43—TEST PIECES OF 15X15 INGOT—LBS. FROM TOP OF INGOT.

Test.	Lbs.	Test.	Lbs.	Test.	Lbs.
Il 10 A1	130	Il 10 B1	1,215	Il 10 C1	2,324
A2	213	B2	1,298	C2	2 407
A3	380	B3	1,465	C3	2,574
A4	496	B4	1,581	C4	2,690
A5	579	B5	1,664	C5	2,773
A6	746	B6	1,831		
A7	862	B7	1,947		
A8	945	B8	2,030		
A9	1,112	B9	2,197		

TABLE 44—TEST PIECES OF 18X18 INGOT—LBS. FROM TOP OF INGOT.

Test.	Lbs.	Test.	Lbs.	Test.	Lbs.	Test.	Lbs.
Il 11 A1	148	Il 11 B1	1,248	Il 11 C1	2,376	Il 11 D1	3,496
A2	231	B2	1,333	C2	2,459	D2	3,579
A3	398	B3	1,498	C3	2,626	D3	3,746
A4	514	B4	1,614	C4	2,742	D4	3,862
A5	597	B5	1,697	C5	2,825	D5	3,945
A6	764	B6	1,864	C6	2,992	D6	4,112
A7	880	B7	1,980	C7	3,108	D7	4,228
A8	963	B8	2,063	C8	3,191	D8	4,311
A9	1,130	B9	2,230	C9	3,358		

TABLE 45—TEST PIECES OF 20X24 INGOT—LBS. FROM TOP OF INGOT.

Test.	Lbs.	Test.	Lbs.	Test.	Lbs.
Il 12 A1	151	Il 12 B1	1,227	Il 12 C1	2,322
A2	234	B2	1,310	C2	2,405
A3	401	B3	1,477	C3	2,572
A4	517	B4	1,593	C4	2,688
A5	600	B5	1,676	C5	2,771
A6	767	B6	1,843	C6	2,938
A7	883	B7	1,959	C7	3,054
A8	966	B8	2,042	C8	3,137
A9	1,133	B9	2,209		

TABLE 45—CONTINUED.

Test.	Lbs.	Test.	Lbs.	Test.	Lbs.
Il 12 D1	3,550	Il 12 E1	4,625	Il 12 F1	5,723
D2	3,663	E2	4,708	F2	5,806
D3	3,800	E3	4,875	F3	5,973
D4	3,916	E4	4,991	F4	6,089
D5	3,999	E5	5,074	F5	6,172
D6	4,166	E6	5,241	F6	6,339
D7	4,282	E7	5,357	F7	6,455
D8	4,365	E8	5,440	F8	6,538
D9	4,532	E9	5,607		

TABLE 46—TEST PIECES OF 25X30 INGOT—LBS. FROM TOP OF INGOT.

Test.	Lbs.	Test.	Lbs.	Test.	Lbs	Test.	Lbs.
Il 13 A1	295	Il 13 B1	1,392	Il 13 C1	2,699	Il 13 D1	3,813
A2	378	B2	1,485	C2	2,782	D2	3,896
A3	545	B3	1,652	C3	2,949	D3	4,063
A4	661	B4	1,768	C4	3,065	D4	4,179
A5	744	B5	1,851	C5	3,148	D5	4,262
A6	911	B6	2,018	C6	3,315	D6	4,429
A7	1,027	B7	2,134	C7	3,431	D7	4,545
A8	1,110	B8	2,217	C8	3,514	D8	4,628
A9	1,277	B9	2,388	C9	3,681	D9	4,795

TABLE 46—CONTINUED.

Test.	Lbs.	Test.	Lbs.	Test.	Lbs.	Test.	Lbs.
Il 13 E1	5,412	Il 13 F1	6,492	Il 13 G1	7,888	Il 13 H1	8,985
E2	5,494	F2	6,575	G2	7,971	H2	9,068
E3	5,662	F3	6,742	G3	8,138	H3	9,235
E4	5,778	F4	6,858	G4	8,254	H4	9,351
E5	5,861	F5	6,941	G5	8,337	H5	9,434
E6	6,028	F6	7,108	G6	8,504	H6	9,601
E7	6,144	F7	7,224	G7	8,620	H7	9,717
E8	6,227	F8	7,307	G8	8,703	H8	9,800
E9	6,394	F9	7,474	G9	8,870	H9	9,967

DROP TESTS.

Six drop tests were made of each full length rail, three with the head in tension, and three with the base in tension, in the standard rail drop test machine. The tup was 2,000 lbs., the height of drop was 20 ft., the supports were 3 ft. apart, and the anvil was the standard spring-supported anvil of 20,000 lbs. The deflection was taken as the distance between a 3-ft. straight edge and the part of the rail where struck by the tup. Gage marks 1 inch apart were put on the side in tension for a distance of 6 inches, and the stretch of each inch was determined after the rail was broken. The results of the drop tests are shown in the following tables:

Table 47—15x15 Ingot.
Table 48—18x18 Ingot.
Table 49—20x24 Ingot.
Table 50—25x30 Ingot.

In these tables the permanent deflection, after the first blow, would represent the stiffness of the rail under impact, and the elongation of the inch which stretched most at breaking would represent the ductility of the metal. The number of blows which it took to break each rail is also shown.

TABLE 47—DROP TESTS OF 15X15 INGOT.

Test.	H or B Tension.	No. of Blows.	Deflection 1st Blow.	1-Inch Marks After Failure. 1.	2.	3.	4.	5.	6.	Remarks.
Il 10 A2	Head	1	....	1.05	....	1.08	1.09	1 08	1.06	
A3	Base	3	1.54	1.06	1.08	1.11	1.13	1.13	....	
A5	Base	3	1.58	1.04	1.08	1.10	1.12	1.13	1.12	Tested base tension by mistake.
A6	Base	4	1.53	1.10	1.12	1.16	1.16	1.14	1.10	
A8	Head	3	1.70	1.06	1.11	1.16	1.19	1.18	1.13	
A9	Base	3	1.65	1.06	1.10	1.12	1.14	1.14	1.12	
Il 10 B2	Head	3	1.70	1.09	1.14	1.18	1.20	1.18	1.14	
B3	Base	1	....	Neglected to put on gage marks.						
B5	Head	3	1.69	1.12	1.14	1.20	1.19	1.15	1.09	
B6	Base	1	....	1.02	1.03	1.03	1.03	1.03	1.02	
B8	Head	4	1.68	1.17	1.22	1.22	1.19	1.14	1.10	Not broken. Bent sidewise.
B9	Base	3	1.68	1.06	1.10	1.13	1.14	1.12	1.10	Diagonal break not at bend.
Il 10 C2	Head	3	1.65	1.09	1.13	1.15	1.14	1.11	1.07	Broke at support.
C3	Base	1	....	1.00	1.02	1.02	1.02	1.02	1.02	Broke at support.
C5	Head	4	1.72	1.09	1.14	1.18	1.18	1.17	1.12	

TABLE 48—DROP TESTS OF 18x18 INGOT.

Test.	H or B Tension.	No. of Blows.	Deflection 1st Blow.	1-Inch Marks After Failure. 1.	2.	3.	4.	5.	6.	Remarks.
Il 11 A2	Head	5	1.92	1.17	1.24	1.32	1.36	1.32	1.22	Not broken. Base split.
A3	Base	4	1.73	1.13	1.16	1.18	1.19	1.19	1.12	
A5	Head	1	....	1.04	1.05	1.06	1.06	....	1.04	
A6	Base	4	1.60	1.14	1.19	1.20	1.18	1.12	1.08	
A8	Head	1	....	1.07	1.09	1.09	1.08	1.06	1.04	
A9	Base	4	1.58	1.11	1.15	1.17	1.17	1.14	....	
Il 11 B2	Head	2	1.69	1.05	1.07	1.09	1.10	1.09	1.06	
B3	Base	5	1.64	1.13	1.18	1.21	1.21	1.20	1.17	
B5	Head	4	1.61	1.14	1.20	1.25	1.25	1.21	1.20	Broke at support.
B6	Base	5	1.70	1.11	1.16	1.22	1.26	1.26	1.21	Broke at support.
B8	Head	4	1.74	1.14	1.19	1.24	1.25	1.22	1.15	
B9	Base	5	1.68	1.18	1.20	1.20	1.17	1.14	1.11	Broke at support.
Il 11 C2	Head	3	1.79	1.07	1.12	1.15	1.18	1.15	....	Base cracked under tup 1st blow.
C3	Base	4	1.65	1.11	1.15	1.17	1.17	1.16	1.12	
C5	Head	3	1.70	1.08	1.12	1.18	1.22	1.22	1.18	
C6	Base	3	1.71	1.08	1.08	1.13	1.13	....	1.08	
C8	Head	3	1.70	1.12	1.16	1.17	1.17	1.13	1.10	Flange broke.
C9	Base	4	1.64	1.10	1.14	1.17	1.18	1.18	1.16	
Il 11 D2	Head	5	1.80	1.08	1.10	1.14	1.21	1.24	1.24	
D3	Base	3	1.64	1.14	1.17	1.18	1.17	1.14	1.10	
D5	Head	4	1.75	1.14	1.18	1.23	1.23	....	1.14	
D6	Base	3	1.66	1.10	1.15	1.17	1.17	1.16	1.12	
D8	Head	3	1.68	1.06	1.10	1.14	1.16	1.17	1.14	

TABLE 49—DROP TESTS OF 20X24 INGOT.

Test.	H or B Tension.	No. of Blows. Deflection 1st Blow.	1-Inch Marks After Failure. 1.	2.	3.	4.	5.	6.	Remarks.
Ii 12 A2	Head	4 1.96	1.13	1.18	1.24	1.22	1.18	1.12	Laminated.
A3	Base	4 1.80	1.12	1.17	1.18	1.17	1.14	1.10	Broke at support.
A5	Head	2 1.84	1.08	1.11	1.13	1.14	....	1.08	
A6	Base	3 1.76	1.08	1.12	1.14	1.13	1.11	1.08	
A8	Head	2 1.71	1.07	1.10	....	1.11	1.10	1.07	
A9	Base	3 1.66	1.12	1.13	1.12	1.09	....	1.08	
Il 12 B2	Head	1	1.04	1.05	1.06	1.06	1.06	1.04	
B3	Base	3 1.59	1.10	1.12	1.12	1.11	1.08	1.06	
B5	Head	2 1.66	1.08	1.10	1.13	1.13	1.10	1.07	
B6	Base	3 1.62	1.08	1.10	1.12	1.12	1.12	1.10	
B8	Head	2 1.66	1.04	1.06	1.08	1.10	1.11	1.12	
B9	Base	3 1.64	1.10	1.13	1.16	1.16	1.12	1.10	
Il 12 C2	Head	2 1.64	1.08	1.12	1.17	1.17	1.13	1.09	
C3	Base	3 1.72	1.06	1.09	1.15	1.20	1.22	1.16	
C5	Head	3 1.64	1.11	1.18	1.20	1.18	1 14	1.09	
C6	Base	3 1.64	1.11	1.16	1.18	1.18	1.14	1.10	
C8	Head	3 1.64	1.10	1.16	1.22	1.22	1.19	1.12	
Il 12 D2	Head	4 1.69	1.14	1.18	1.20	1.20	1.16	....	
D3	Base	5 1.62	1.16	1.19	1.19	1.18	1.14	....	
D5	Head	4 1.72	1.15	1.20	1.24	1.23	1.18	1.11	
D6	Base	5 1.58	1.12	1.17	1.20	1.22	1.20	....	
D8	Head	4 1.65	1.18	1.24	1.26	1.22	....	1.10	
D9	Base	4 1.62	1.12	1.16	1.20	1.20	1.18	1.14	
Il 12 E2	Head	4 1.74	1.18	1.21	1.20	....	1.11	1.06	
E3	Base	5 1.65	1.15	1.20	1.22	1.22	1.18	1.12	
E5	Head	4 1.69	1.14	1.18	1.21	1.22	1.17	1.13	
E6	Base	5 1.73	1.10	1.14	1.19	1.20	1.20	1.18	
E8	Head	4 1.75	1.08	1.10	1.13	1.19	1.22	1.22	
E9	Base	3 1.69	1.08	1.12	1.14	1.16	1.15	1.13	Broke at support.
Il 12 F2	Head	3 1.74	1.10	1.14	1.17	1.17	....	1.10	
F3	Base	3 1.68	1.08	1.11	1.15	1.17	1.17	1.15	
F5	Head	3 1.68	1.14	1.21	1.25	1.25	1.19	1.12	
F6	Base	4 1.70	1.10	1.14	1.18	1.17	1.16	1.13	
F8	Head	1	1.02	1.04	1.04	1.05	1.04	1.03	Large horizontal flaw in head.

TABLE 50—DROP TESTS OF 25X30 INGOT.

Test.	H or B Tension.	No. of Blows.	Deflection 1st Blow.	1-Inch Marks After Failure. 1.	2.	3.	4.	5.	6.	Remarks.
Il 13 A2	Head	5	2.12	1.19	1.24	1.26	1.24	1.18	1.14	Not broken.
A3	Base	4	1.93	1.12	1.17	1.22	1.26	1.26	1.23	Laminated in web.
A5	Head	3	1.92	1.12	1.18	1.21	1.20	1.16	1.11	
A6	Base	5	1.82	1.08	1.14	1.18	1.24	1.32	1.36	Base not broken.
A8	Head	2	1.86	1.07	1.10	1.14	1.15	1.14	1.10	
A9	Base	2	1.82	1.07	1.10	1.11	1.12	1.11	1.08	
Il 13 B2	Head	1	....	1.06	1.07	1.08	1.08	1.08	1.07	
B3	Base	3	1.78	1.12	1.16	1.19	1.24	1.18	1.14	
B5	Head	1	....	1.02	1.04	1.05	1.07	1.05	1.04	
B6	Base	2	1.72	1.06	1.08	1.10	1.11	1.10	1.07	
B8	Head	1	....	1.02	1.04	1.07	1.08	1.07	1.06	
B9	Base	2	1.72	1.07	1.08	1.10	1.12	1.11	1.08	
Il 13 C2	Head	2	1.68	1.09	1.09	1.08	1.06	....	1.06	
C3	Base	2	1.66	1.04	1.07	1.10	1.12	1.14	1.12	
C5	Head	2	1.68	1.04	1.07	1.10	1.15	1.20	1.15	
C6	Base	4	1.62	1.09	1.14	1.18	1.20	1.22	1.17	
C8	Head	2	1.68	1.05	1.07	1.10	1.11	1.10	1.07	
C9	Base	4	1.59	1.12	1.15	1.17	1.17	1.16	....	
Il 13 D2	Head	3	1.52	1.07	1.12	1.16	1.19	1.17	1.12	
D3	Base	4	1.58	1.11	1.16	1.18	1.16	1.16	1.12	
D5	Head	3	1.60	1.08	1.12	1.18	1.18	1.17	1.12	
D6	Base	4	1.58	1.10	1.16	1.18	1.18	1.17	1.14	
D8	Head	3	1.65	1.12	1.18	1.20	1.18	1.14	1.08	
D9	Base	4	1.58	1.06	1.10	1.14	1.18	1.18	1.15	

TABLE 50—CONTINUED.

Test.	H or B Tension.	No. of Blows.	Deflection 1st Blow.	1-Inch Marks After Failure. 1.	2.	3.	4.	5.	6.	Remarks.
Il 13 E2	Head	2	1.61	1.04	1.07	1.10	1.11	1.11	1.09	
E3	Base	3	1.58	1.08	1.12	1.14	1.14	1.12	1.08	
E5	Head	2	1.74	1.08	1.10	1.12	1.12	1.09	1.07	
E6	Base	4	1.60	1.08	1.12	1.15	1.15	1.14	1.10	Broke at both supports.
E8	Head	2	1.72	1.12	1.16	1.16	1.15	1.13	1.07	
E9	Base	3	1.66	1.08	1.11	1.14	1.16	1.15	....	
Il 13 F2	Head	3	1.70	1.06	1.12	1.17	1.20	1.18	1.14	
F3	Base	4	1.67	1.08	1.12	1.16	1.18	1.18	1.16	
F5	Head	4	1.76	1.10	1.15	1.20	1.23	1.26	1.20	
F6	Base	5	1.77	1.12	1.18	1.20	1.20	1.18	1.14	
F8	Head	3	1.74	1.14	1.18	1.20	1.20	1.16	1.10	Only side of base broken.
F9	Base	4	1.70	1.12	1.16	1.18	1.18	1.16	1.14	
Il 13 G2	Head	5	1.86	1.10	1.14	1.21	1.25	1.32	1.28	
G3	Base	5	1.72	1.12	1.17	1.20	1.20	1.18	1.14	
G5	Head	3	1.84	1.06	1.11	1.16	1.22	1.22	1.18	
G6	Base	3	1.73	1.12	1.13	1.16	1.16	1.13	1.08	
G8	Head	4	1.89	1.10	1.12	1.18	1.23	1.27	1.26	
G9	Base	4	1.73	1.14	1.18	1.22	1.21	1.18	1.13	
Il 13 H2	Head	3	1.80	1.12	1.16	1.22	1.20	1.16	1.10	
H3	Base	4	1.73	1.13	1.20	1.22	1.24	1.23	1.18	
H5	Head	5	1.78	1.14	1.24	1.36	1.45	1.39	1.26	
H6	Base	5	1.72	1.10	1.14	1.16	1.18	1.17	1.16	Not broken.
H8	Head	4	1.71	1.23	1.34	1.36	1.29	1.20	1.13	
H9	Base	4	1.74	1.15	1.17	1.18	1.15	1.13	1.08	

DUCTILITY.

The results showing the ductility of the rails in the drop test, are shown in Fig. 16, in which the distance of the piece tested is shown horizontally in pounds from the top of the ingot and the elongation of the metal at breaking is shown vertically. The per cent. of elongation of the inch which stretched most is taken as representing the ductility. A close study of these diagrams proves very interesting. Considering the 18x18, 20x24 and 25x30 ingots, it will be noticed that the rail bar at the top end shows a good ductility, which rapidly decreases as we pass through a "brittle zone" about 20 per cent. from the top of the ingot. The ductility again increases until a distance of about 50 per cent. from the top of the ingot is reached, after which the change of ductility is not great. The rail bar from the 15x15 ingot shows a somewhat similar result, except that the brittle zone starts in with the topmost pieces tested, although it is possible, or even probable, that the material of good ductility at the top of this small ingot was cut off with the portion which it was necessary to crop off the top end of the bloom before rolling. Another point of considerable interest is that the top half of the ingot shows greater ductility when tested with the base in tension than with the head in tension, especially in the brittle zone, but the lower half shows somewhat greater ductility when tested with the head in tension. This does not, however, necessarily mean that the rail from the lower part of the ingot would stand more impact with head tension, since a given impact causes considerably more stretch when the head is in tension than when the base is in tension, although the deflection of the rail is about the same.

In order to more conveniently compare the results from the different ingots the average results in the head tension tests are shown together in Fig. 17, and the results of the base tension tests are also shown together by themselves, also in Fig. 17. Two of the base tension results of 15x15 ingot, Nos. Il 10 B6 and Il 10 C3, gave very low elongation. It seems very probable that these results were abnormal and were not used in drawing the average curve. Likewise, the last piece from the 20x24 ingot tested with head tension, broke with very low elongation, evidently due to an internal flaw in the head, and this result was not considered. It will be noticed that in the brittle zone, which is about 20 per cent. from the top of the ingot, with head tension, fracture occurs at about 6 or 7 per cent. stretch, and the ductility is about the same in the various ingots. In the lower half of the ingot the elongation goes up over 20 per cent., increasing somewhat with the size of the ingot. At the top of the ingot also the elongation is over 20 per cent. With base tension the minimum elongation is about 12 per cent., except in the 18x18 ingot, which showed a minimum of 17 per cent. In the lower half of the ingot the elongation is about 20 per cent. for the different ingots. As already explained, the 20x24 and 25x30 ingots had to be bloomed down somewhat and cut in two before the rail mill could take them. The two parts of the 20x24 ingot showed a continuity of results in the drop

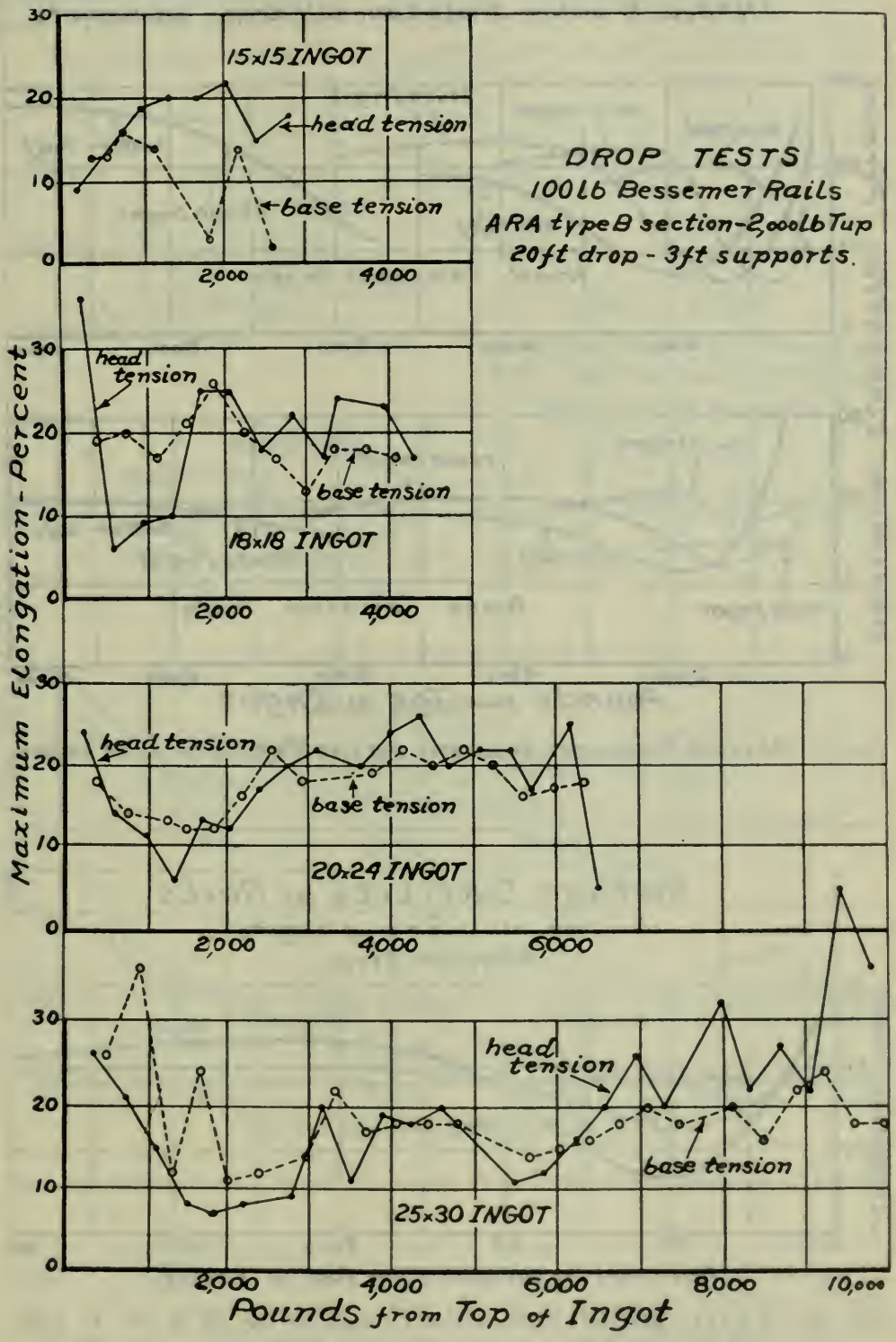


FIG. 16—ELONGATION DIAGRAMS WITH THE INDIVIDUAL RESULTS PLOTTED.

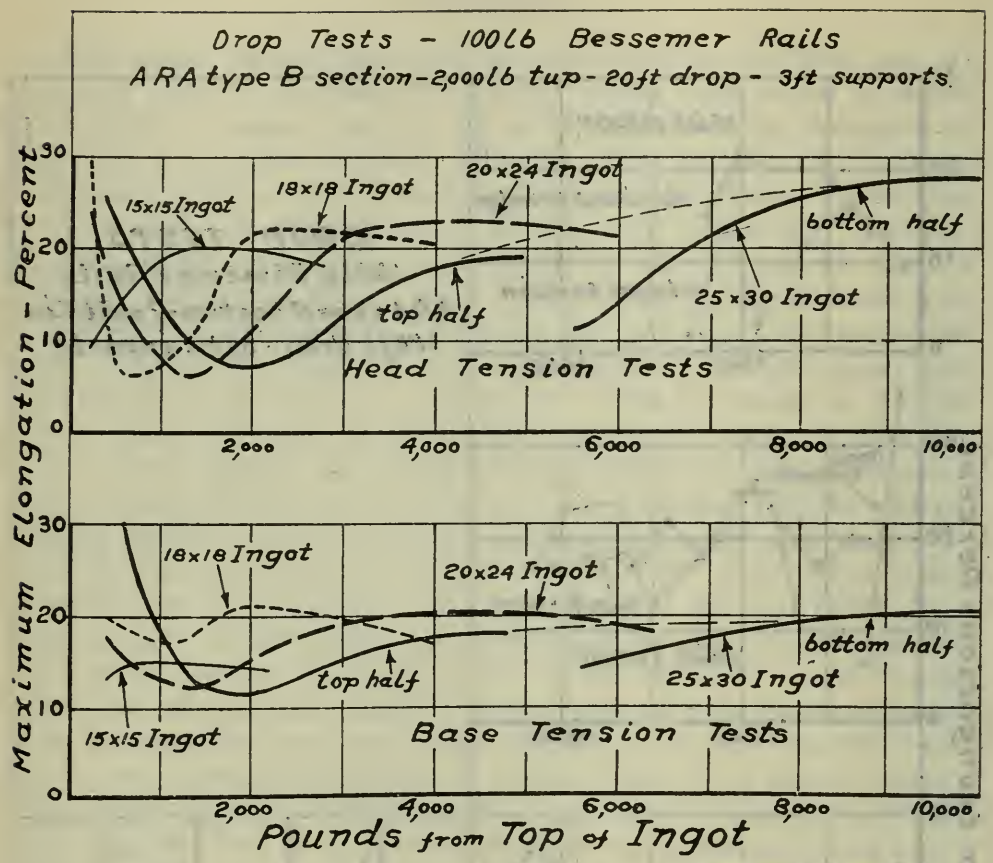


FIG. 17—AVERAGE ELONGATION DIAGRAMS FOR THE VARIOUS SIZES OF INGOTS.

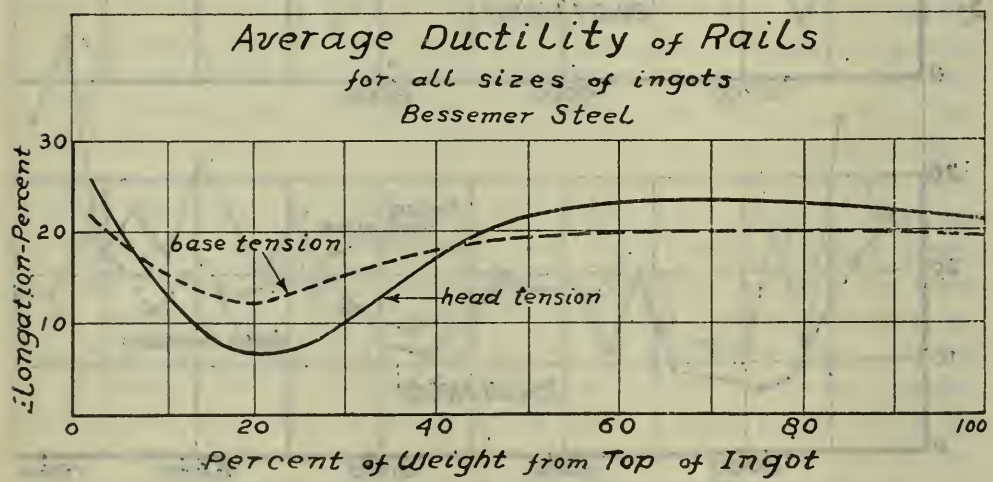


FIG. 18—"CHARACTERISTIC" ELONGATION CURVES OF 100 LB. A. R. A. TYPE B SECTION RAILS MADE OF BESSEMER STEEL FROM VARIOUS SIZES OF INGOTS.

tests, but in the 25x30 ingot, the upper end of the lower half shows a considerable drop in ductility in both the head tension and base tension tests. Why this should be I am unable to say.

The ductility curves of the various sized ingots are a good deal alike, and one average curve for head tension and another for base

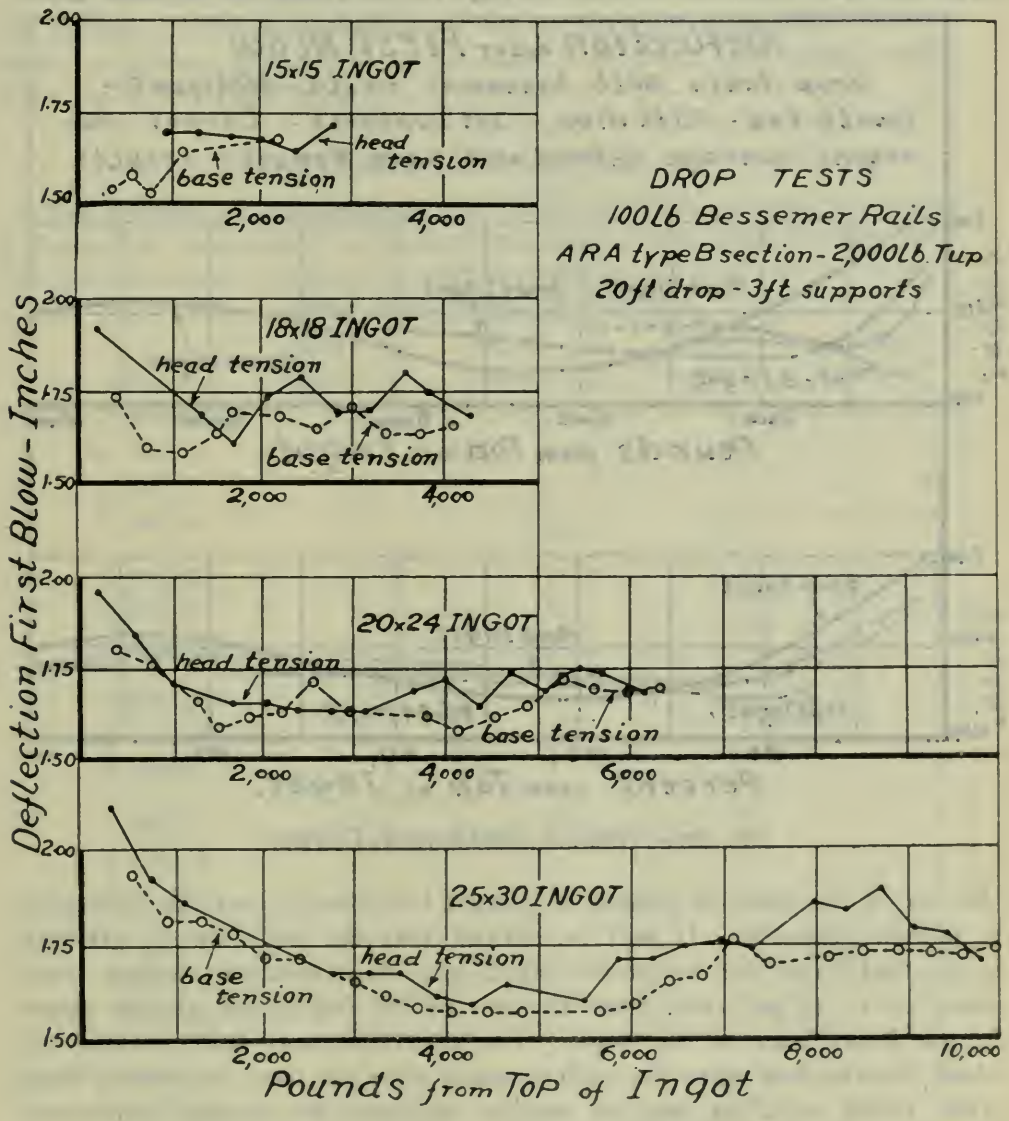


FIG. 19—DEFLECTION DIAGRAMS WITH THE INDIVIDUAL RESULTS PLOTTED.

tension, representing distance from top in per cent. of total weight of ingot, represent the various ingots nicely. I show such curves in Fig. 18, and these may be called the "characteristic" ductility curves of these rails made from Bessemer steel. The point of most interest and importance is probably the zone of least ductility, which occurs at about 20 per cent. from the top of the ingot, and in this zone the

ductility, when the rail is tested with the head in tension, is about half of what it is when tested with the base in tension. In the lower half of the ingot the rail shows a little more ductility when tested with the head in tension.

DEFLECTION.

The results of the drop tests, showing deflection or permanent set after the first blow, are plotted in Fig. 19, in which the distance from

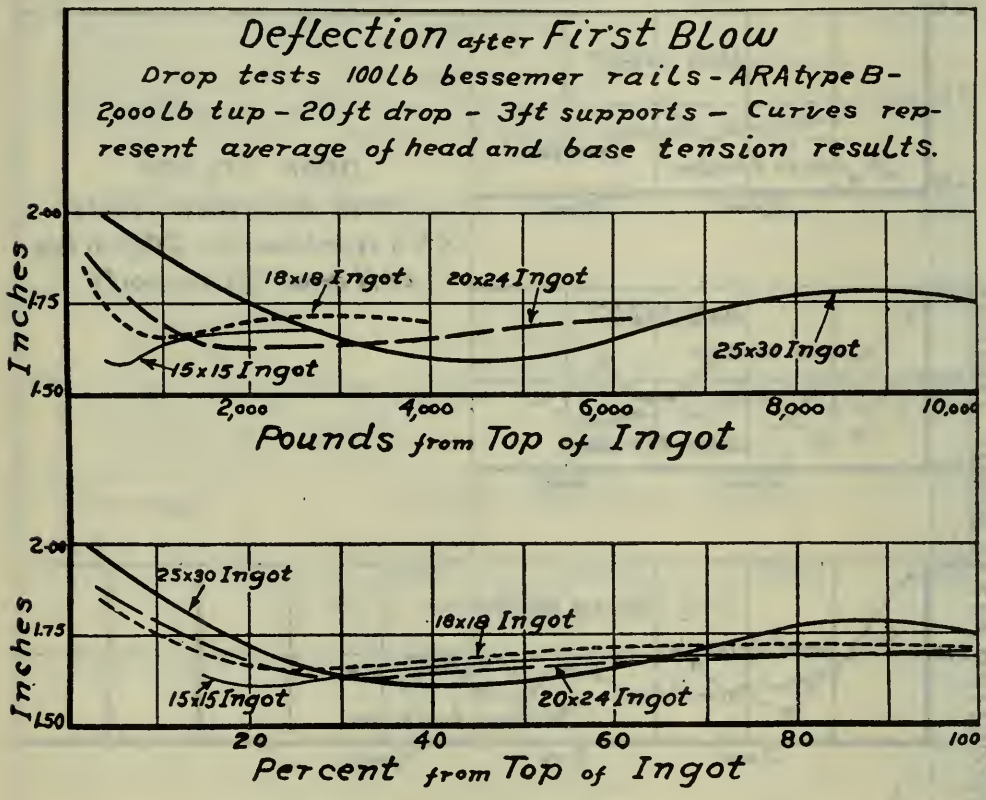


FIG. 20—AVERAGE DEFLECTION CURVES.

the top of the ingot in pounds is plotted horizontally and the deflection is plotted vertically. It will be noticed that the deflection is greatest in the rail from the top of the ingot, least at a distance varying from about 20 to 45 per cent. from the top of the ingot, and greater again in the lower part of the ingot. The deflection is a little greater all along the rail bar when the rail is tested with the head in tension than when tested with the base in tension, although the average difference amounts to only several hundredths of an inch. In Fig. 20 I give curves showing the average of the head tension and base tension results for each ingot, one set of curves on the basis of distance from the top of the ingot in pounds, and the other set on the basis of distance from the top in per cent. of the total weight of the ingot. The deflection with head tension would average slightly greater than shown, and with base tension slightly less. These curves indicate that the zone of least deflection or of maximum stiffness under the drop moves downward as

the size of the ingot increases, and they indicate roughly that these zones occur at the following distances from the top of the ingot:

15x15 ingot.....20 per cent.
18x18 " .....25 "
20x24 " .....30 "
25x30 " .....40 "

The average minimum deflection ranges between 1.60 and 1.65 inches. The average maximum deflection of the 15x15, 18x18 and 20x24 ingots is about 1.70 inches, and of the 25x30 ingot it is about 1.78 inches, except at the top of the ingot where it is greater.

NUMBER OF BLOWS.

The number of blows which was applied to each piece of rail tested is shown for convenience of comparison in table 51. The number given

TABLE 51—NUMBER OF BLOWS.

Rail.	Piece Number	15x15 Ingot. H. T.	15x15 Ingot. B. T.	18x18 Ingot. H. T.	18x18 Ingot. B. T.	20x24 Ingot. H. T.	20x24 Ingot. B. T.	25x30 Ingot. H. T.	25x30 Ingot. B. T.
A	2 and 3	1	3	5	4	4	4	5	4
	5 and 6	..	4	1	4	2	3	3	5
	8 and 9	3	3	1	4	2	3	2	2
B	2 and 3	3	1	2	5	1	3	1	3
	5 and 6	3	1	4	5	2	3	1	2
	8 and 9	4	3	4	5	2	3	1	2
C	2 and 3	3	1	3	4	2	3	2	2
	5 and 6	4	..	3	3	3	3	2	4
	8 and 9	..	..	3	4	3	3	2	4
D	2 and 3	..	..	5	3	4	5	3	4
	5 and 6	..	..	4	3	4	5	3	4
	8 and 9	..	..	3	..	4	4	3	4
E	2 and 3	..	..	..	..	4	5	2	3
	5 and 6	..	..	..	..	4	5	2	4
	8 and 9	..	..	..	..	4	3	2	3
F	2 and 3	..	..	..	..	3	3	3	4
	5 and 6	..	..	..	..	3	4	4	5
	8 and 9	..	..	..	..	1	..	3	4
G	2 and 3	..	..	..	..	..	..	5	5
	5 and 6	..	..	..	..	..	..	3	3
	8 and 9	..	..	..	..	..	..	4	4
H	2 and 3	..	..	..	..	..	..	3	4
	5 and 6	..	..	..	..	..	..	5	5
	8 and 9	..	..	..	..	..	..	4	4

shows the number of blows which broke the rail, except in a few cases where the rail did not break. These results are plotted in Fig. 21 for more convenient comparison. It will be noticed that with the head in tension all of the ingots gave one or more tests that broke on the first blow from 20 ft. With the base in tension the 15x15 ingot gave three tests that broke on the first blow, although, as already noted, these seem

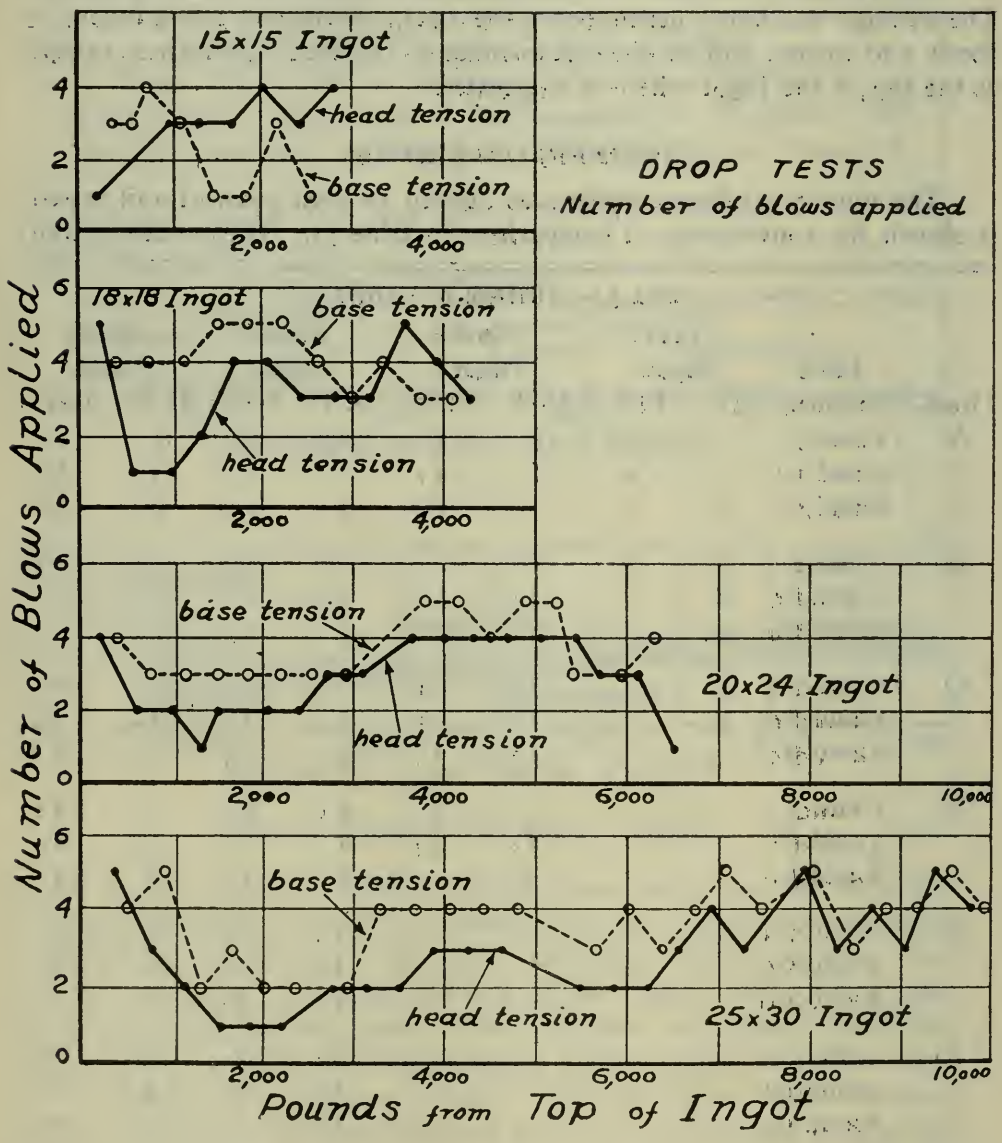


FIG. 21—DIAGRAMS OF THE NUMBER OF BLOWS THAT BROKE THE RAILS IN THE DROP TEST.

to be abnormal, due possibly to some delays in rolling or other unexplained cause. The 18x18 and 20x24 ingots, with the base in tension, gave a minimum number of three blows in any one test. With the 25x30 ingot the minimum was two blows. The general appearance of the various

diagrams suggests that the upper part of the ingot stands a decreasing total height of drop with the base in tension, as the size of the ingot increases.

ANALYSIS OF RAILS.

As already explained, analyses were made of samples taken each eleven feet along the rail bar. From each section three samples were

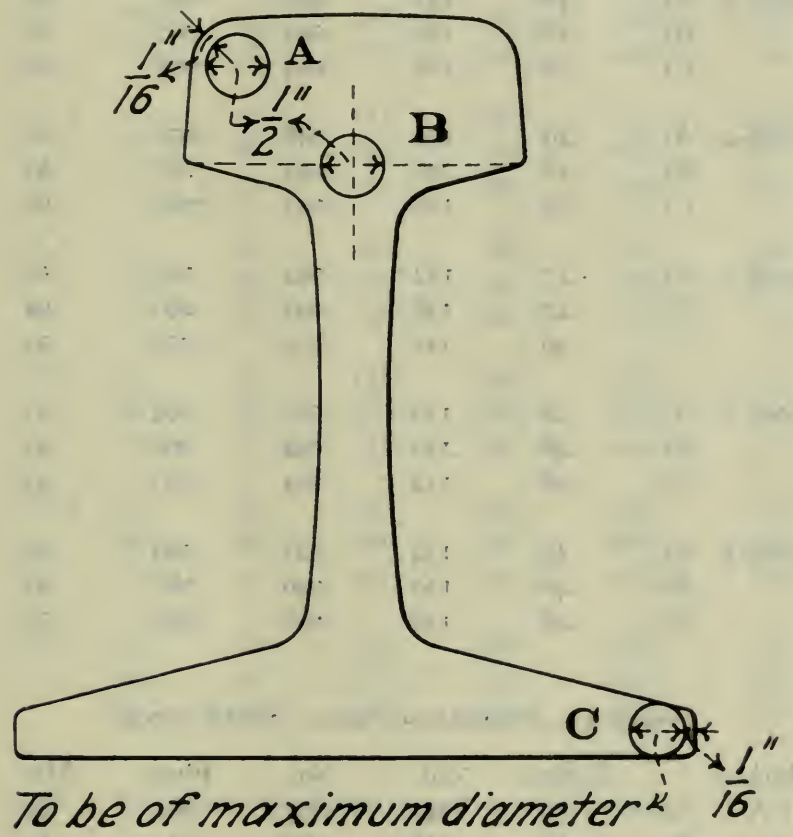


FIG. 22—DRILLING DIAGRAM FOR BORINGS FOR ANALYSIS FROM RAILS.

taken as shown in Fig. 22, A from the upper corner of the head, B from the interior of the head near its junction with the web, and C from near the edge of the flange, which are the locations recommended by the Rail Committee in March, 1911. The analyses are shown in tables 52 to 55, inclusive.

TABLE 52—ANALYSIS OF RAILS, 15X15 INGOT.

Marked		Carbon	Sil.	Sul.	Phos.	Mn.
10-A-1	A1	.39	.135	.029	.065	.94
	B1	.44	.137	.039	.081	.94
	C1	.43	.133	.029	.065	.89
10-A-4	A1	.51	.144	.046	.098	.94
	B1	.56	.146	.061	.119	.97
	C1	.50	.147	.046	.094	.94

TABLE 52—ANALYSIS OF RAILS, 15X15 INGOT—*Continued.*

Marked		Carbon	Sil.	Sul.	Phos.	Mn.
10-A-7	A1	.49	.138	.046	.094	.98
	B1	.52	.134	.052	.102	.95
	C1	.50	.139	.047	.094	.96
10-B-1	A1	.48	.134	.046	.097	.95
	B1	.48	.126	.044	.097	.95
	C1	.50	.118	.044	.098	.96
10-B-4	A1	.49	.139	.048	.098	.96
	B1	.48	.126	.043	.095	.93
	C1	.49	.126	.043	.096	.96
10-B-7	A1	.47	.142	.044	.094	.94
	B1	.47	.138	.042	.090	.94
	C1	.49	.144	.042	.092	.94
10-C-1	A1	.48	.130	.042	.094	.93
	B1	.48	.130	.044	.090	.93
	C1	.48	.134	.044	.093	.93
10-C-4	A1	.49	.134	.044	.093	.93
	B1	.46	.130	.040	.087	.93
	C1	.48	.130	.046	.092	.93

TABLE 53—ANALYSES OF RAILS, 18X18 INGOT.

Marked		Carbon	Sil.	Sul.	Phos.	Mn.
11-A-1	A1	.35	.144	.027	.061	.89
	B1	.56	.148	.056	.117	.97
	C1	.40	.141	.029	.064	.91
11-A-4	A1	.44	.140	.034	.078	.88
	B1	.66	.147	.084	.164	1.00
	C1	.45	.148	.039	.082	.89
11-A-7	A1	.49	.145	.046	.092	.93
	B1	.64	.143	.078	.154	1.00
	C1	.48	.143	.045	.095	.93
11-B-1	A1	.49	.138	.044	.096	.92
	B1	.56	.139	.053	.108	.93
	C1	.49	.138	.044	.093	.91
11-B-4	A1	.48	.136	.044	.093	.92
	B1	.49	.138	.049	.100	.93
	C1	.49	.136	.049	.096	.94

TABLE 53—ANALYSIS OF RAILS, 18x18 INGOT—*Continued.*

Marked		Carbon	Sil.	Sul.	Phos.	Mn.
11-B-7	A1	.50	.134	.046	.095	.92
	B1	.48	.131	.044	.090	.92
	C1	.49	.135	.045	.093	.93
11-C-1	A1	.49	.136	.046	.095	.92
	B1	.45	.131	.045	.088	.91
	C1	.49	.130	.044	.093	.92
11-C-4	A1	.49	.143	.046	.095	.92
	B1	.48	.144	.043	.085	.92
	C1	.49	.139	.044	.093	.93
11-C-7	A1	.49	.139	.046	.094	.92
	B1	.46	.139	.041	.083	.91
	C1	.45	.136	.044	.095	.92
11-D-1	A1	.50	.144	.044	.095	.91
	B1	.46	.141	.040	.083	.90
	C1	.51	.135	.042	.092	.91
11-D-4	A1	.50	.147	.045	.095	.92
	B1	.47	.138	.046	.081	.91
	C1	.49	.145	.044	.092	.91
11-D-7	A1	.50	.133	.048	.093	.94
	B1	.47	.135	.047	.091	.93
	C1	.46	.136	.046	.094	.93

TABLE 54—ANALYSES OF RAILS, 20X24 INGOT.

Marked		Carbon	Sil.	Sul.	Phos.	Mn.
12-A-1	A1	.41	.131	.029	.063	.94
	B1	.40	.133	.029	.061	.91
	C1	.45	.128	.030	.065	.92
12-A-4	A1	.45	.128	.032	.077	.94
	B1	.47	.131	.040	.088	.93
	C1	.42	.127	.029	.069	.91
12-A-7	A1	.47	.133	.043	.087	.93
	B1	.64	.137	.067	.135	.99
	C1	.49	.139	.043	.086	.93
12-B-1	A1	.52	.134	.048	.094	.93
	B1	.59	.136	.069	.134	1.00
	C1	.51	.131	.048	.094	.94

TABLE 54—ANALYSIS OF RAILS, 20X24 INGOT—*Continued.*

Marked		Carbon	Sil.	Sul.	Phos.	Mn.
12-B-4	A1	.49	.131	.050	.097	.95
	B1	.60	.132	.065	.125	.98
	C1	.49	.132	.049	.096	.95
12-B-7	A1	.49	.135	.048	.094	.95
	B1	.58	.141	.059	.114	.98
	C1	.48	.136	.048	.094	.94
12-C-1	A1	.52	.145	.047	.095	.95
	B1	.56	.145	.052	.102	.95
	C1	.50	.137	.045	.093	.93
12-C-4	A1	.50	.144	.044	.096	.94
	B1	.53	.145	.044	.097	.93
	C1	.50	.147	.045	.095	.93
12-C-7	A1	.51	.134	.048	.098	.97
	B1	.49	.132	.047	.095	.94
	C1	.52	.132	.046	.096	.96
12-D-1	A1	.50	.143	.044	.094	.93
	B1	.48	.143	.043	.096	.93
	C1	.50	.144	.044	.092	.92
12-D-4	A1	.47	.134	.048	.095	.96
	B1	.48	.134	.047	.094	.95
	C1	.46	.135	.046	.095	.95
12-D-7	A1	.52	.133	.044	.097	.95
	B1	.49	.127	.042	.093	.94
	C1	.51	.135	.044	.095	.96
12-E-1	A1	.51	.130	.046	.097	.95
	B1	.48	.128	.043	.089	.92
	C1	.51	.131	.049	.096	.95
12-E-4	A1	.51	.134	.044	.095	.93
	B1	.47	.134	.039	.084	.91
	C1	.51	.132	.044	.093	.95
12-E-7	A1	.50	.132	.044	.094	.95
	B1	.45	.130	.039	.085	.93
	C1	.50	.126	.043	.092	.94
12-F-1	A1	.52	.133	.046	.094	.95
	B1	.47	.131	.040	.083	.92
	C1	.51	.131	.046	.093	.94

TABLE 54—ANALYSIS OF RAILS, 20X24 INGOT—*Continued.*

Marked		Carbon	Sil.	Sul.	Phos.	Mn.
12-F-4	A1	.51	.130	.044	.092	.93
	B1	.47	.130	.044	.087	.92
	C1	.51	.131	.047	.094	.94
12-F-7	A1	.50	.130	.049	.096	.94
	B1	.51	.132	.045	.094	.92
	C1	.51	.138	.041	.092	.92

TABLE 55—ANALYSES OF RAILS, 25X30 INGOT.

Marked		Carbon	Sil.	Sul.	Phos.	Mn.
13-A-1	A1	.35	.152	.025	.055	.89
	B1	.35	.152	.024	.048	.89
	C1	.38	.134	.027	.063	.88
13-A-4	A1	.33	.130	.027	.057	.87
	B1	.49	.139	.042	.098	.95
	C1	.37	.130	.029	.063	.88
13-A-7	A1	.41	.126	.029	.065	.88
	B1	.51	.153	.046	.092	.97
	C1	.42	.129	.036	.071	.88
13-B-1	A1	.40	.130	.034	.068	.89
	B1	.66	.161	.081	.160	1.04
	C1	.40	.129	.029	.065	.90
Marked		Carbon	Sil.	Sul.	Phos.	Mn.
13-B-4	A1	.44	.130	.036	.076	.91
	B1	.77	.152	.025	.210	1.06
	C1	.45	.131	.032	.072	.91
13-B-7	A1	.44	.129	.037	.072	.89
	B1	.79	.146	.136	.187	1.08
	C1	.43	.128	.032	.066	.89
13-C-1	A1	.45	.130	.030	.077	.93
	B1	.72	.134	.102	.174	1.04
	C1	.45	.134	.033	.075	.92
13-C-4	A1	.44	.129	.037	.077	.93
	B1	.61	.152	.085	.155	1.00
	C1	.45	.131	.041	.080	.95
13-C-7	A1	.43	.129	.040	.084	.89
	B1	.58	.139	.067	.128	.98
	C1	.50	.130	.042	.092	.94

TABLE 55—ANALYSIS OF RAILS, 25X30 INGOT—*Continued.*

Marked		Carbon	Sil.	Sul.	Phos.	Mn.
13-D-1	A1	.48	.144	.039	.090	.92
	B1	.52	.135	.045	.106	.94
	C1	.50	.142	.040	.093	.92
13-D-4	A1	.50	.130	.048	.094	.96
	B1	.57	.136	.060	.123	.97
	C1	.49	.130	.046	.095	.91
13-D-7	A1	.50	.126	.047	.096	.94
	B1	.53	.144	.057	.117	.95
	C1	.51	.150	.051	.099	.93
13-E-1	A1	.50	.134	.049	.101	.92
	B1	.50	.130	.055	.109	.94
	C1	.48	.140	.045	.094	.91
13-E-4	A1	.49	.160	.047	.097	.93
	B1	.52	.144	.057	.109	.92
	C1	.47	.134	.043	.093	.91
13-E-7	A1	.50	.138	.048	.103	.92
	B1	.52	.125	.052	.105	.96
	C1	.47	.128	.045	.096	.94
13-F-1	A1	.49	.148	.048	.097	.92
	B1	.47	.138	.049	.094	.92
	C1	.48	.136	.045	.094	.93
13-F-4	A1	.51	.134	.053	.101	.95
	B1	.44	.141	.039	.087	.93
	C1	.50	.128	.049	.097	.93
13-F-7	A1	.49	.144	.048	.098	.94
	B1	.43	.143	.042	.081	.92
	C1	.49	.145	.046	.095	.93
13-G-1	A1	.47	.128	.043	.095	.93
	B1	.39	.127	.039	.075	.89
	C1	.48	.128	.044	.095	.94
13-G-4	A1	.49	.135	.040	.095	.95
	B1	.42	.138	.038	.075	.92
	C1	.49	.141	.042	.094	.94
13-G-7	A1	.47	.134	.045	.092	.94
	B1	.39	.140	.038	.073	.89
	C1	.50	.134	.045	.094	.97
13-H-1	A1	.49	.130	.046	.093	.94
	B1	.40	.132	.033	.074	.88
	C1	.50	.146	.045	.089	.92

TABLE 55—ANALYSIS OF RAILS, 25X30 INGOT—*Continued.*

Marked		Carbon	Sil.	Sul.	Phos.	Mn.
13-H-4	A1	.46	.135	.043	.092	.93
	B1	.44	.136	.041	.080	.90
	C1	.49	.134	.045	.095	.91
13-H-7	A1	.47	.142	.046	.092	.91
	B1	.47	.136	.046	.091	.92
	C1	.50	.136	.045	.092	.91

In order to show the chemistry in convenient form for comparison, I have plotted the carbon results from the corner of the head and from

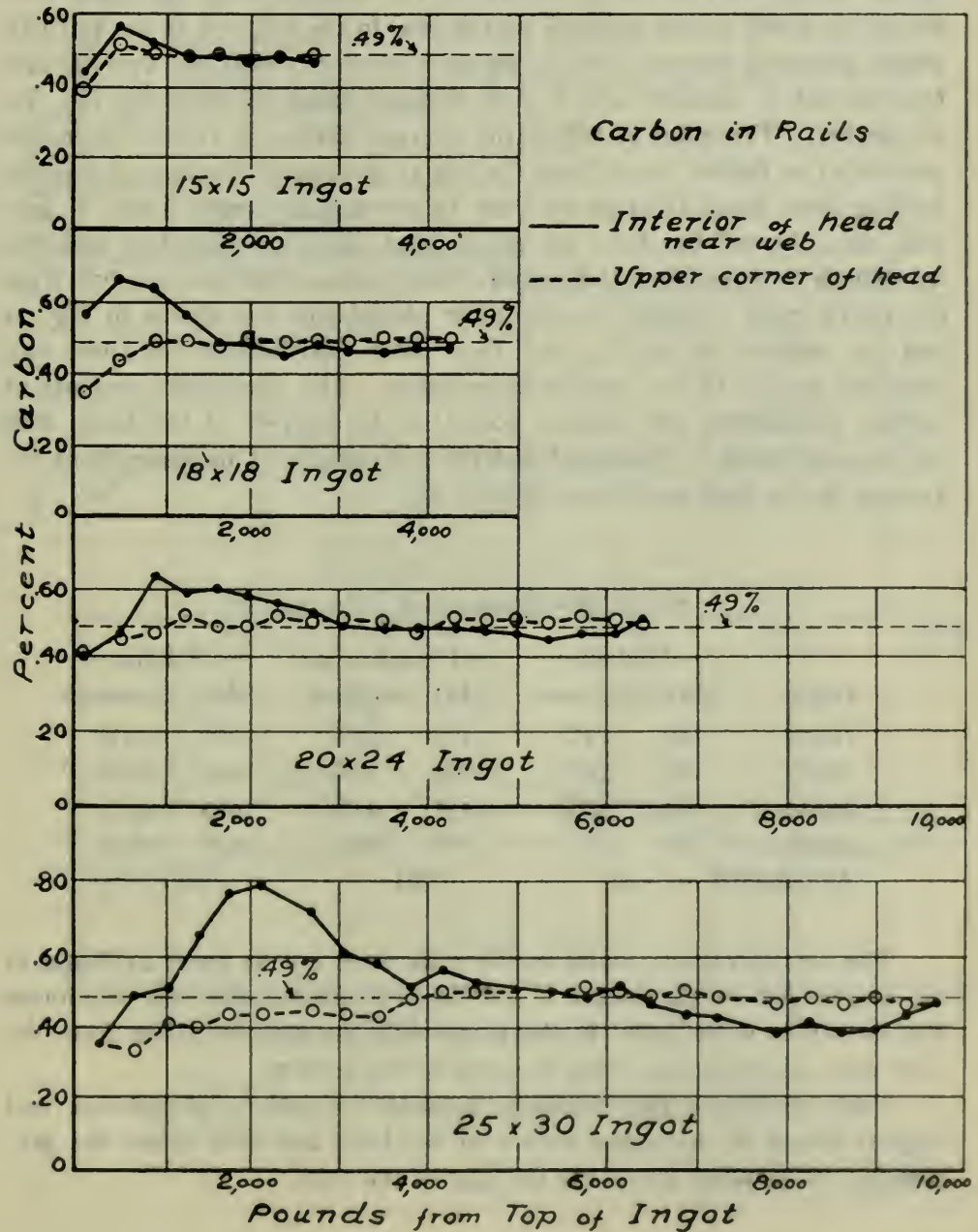


FIG. 23—DIAGRAMS OF CARBON IN RAILS.

the interior of the head in Fig. 23, in which the distance from the top of the ingot in pounds is shown horizontally and the per cent. of carbon is shown vertically. In a general way, these diagrams show conditions already found in the ingot. The average carbon in the heat, as indicated by the samples from the upper corner of the head in the lower end of the rail bar, was .49 per cent. The interior of the rail at the top end of the rail bar shows negative segregation, but going down the ingot, it soon develops considerable positive segregation, which reaches a maximum at about 20 per cent. by weight from the top. The lower end of the rail bar again shows negative segregation in the interior. The outer portion of the section of the rail, as shown by the samples from the upper corner of the head, shows negative segregation in the top end of the rail bar, which gradually becomes less as we go downward, until the average carbon content is reached, which then remains about constant for the rest of the bar. The point at which the average carbon is reached seems in general to be farther down from the top as the size of the ingot increases, varying from about 15 or 20 per cent. to about 35 per cent. I say, in general, since the rail bar from the 20x24 ingot seems to show less variation as regards both positive and negative segregation than the rail bar from the 18x18 ingot. Similar diagrams for phosphorus are shown in Fig. 24 and for sulphur in Fig. 25, and they show distributions for these two elements similar to the carbon distribution. The maximum amounts of carbon, phosphorus and sulphur found in the interior of the head, with the samples taken as explained and the percentages of increase above the average in the heat, are shown in table 56.

TABLE 56—SEGREGATION IN RAILS.

	——Carbon——		—Phosphorus—		——Sulphur——	
Ingot	Max.	Increase	Max.	Increase	Max.	Increase
15x15	.56	14%	.119	27%	.061	33%
18x18	.66	35%	.164	75%	.084	83%
20x24	.64	31%	.135	44%	.069	50%
25x30	.79	61%	.210	123%	.136	195%
Ave. in heat	.49		.094		.045	

The concentrations found in the rails were not as great as found in the ingots, but in the ingots it will be remembered that the maximum concentrations were found in the axis, while the samples taken from the rails were some distance from the axis of the section.

Table 57 shows the minimum amounts of carbon, phosphorus and sulphur found in the upper corner of the head and also shows the percentages of decrease below the average in the heat.

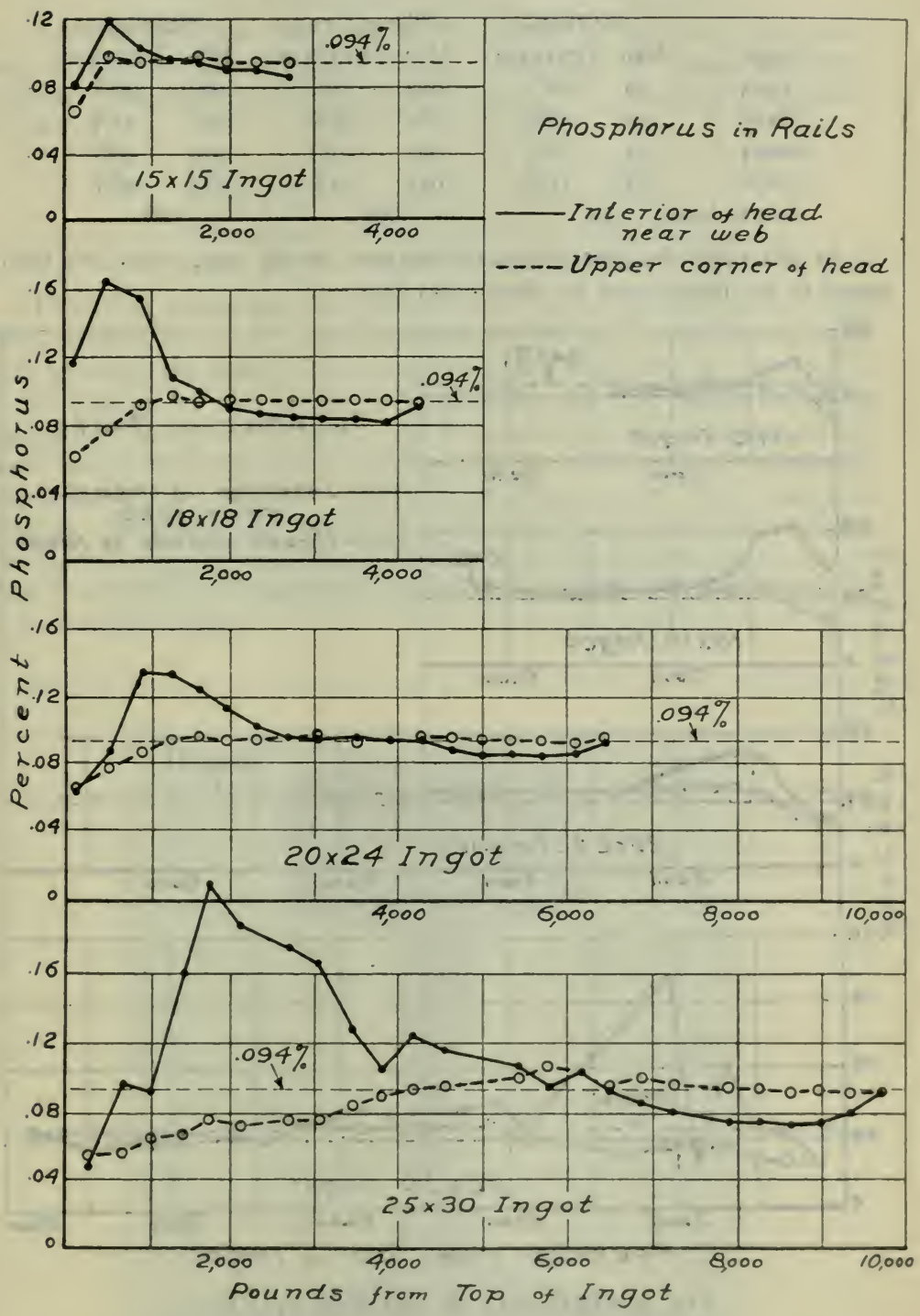


FIG. 24—DIAGRAMS OF PHOSPHORUS IN RAILS

TABLE 57—NEGATIVE SEGREGATION IN RAILS.

	—Carbon—		—Phosphorus—		—Sulphur—	
Ingot	Min.	Decrease	Min.	Decrease	Min.	Decrease
15x15	.39	20%	.065	31%	.029	37%
18x18	.35	29%	.061	36%	.027	41%
20x24	.41	16%	.063	33%	.029	37%
25x30	.33	33%	.055	43%	.025	46%
Ave. in heat	.49		.094		.046	

In this table the percentages of decrease are in some cases less than found in the ingots, and in other cases more.

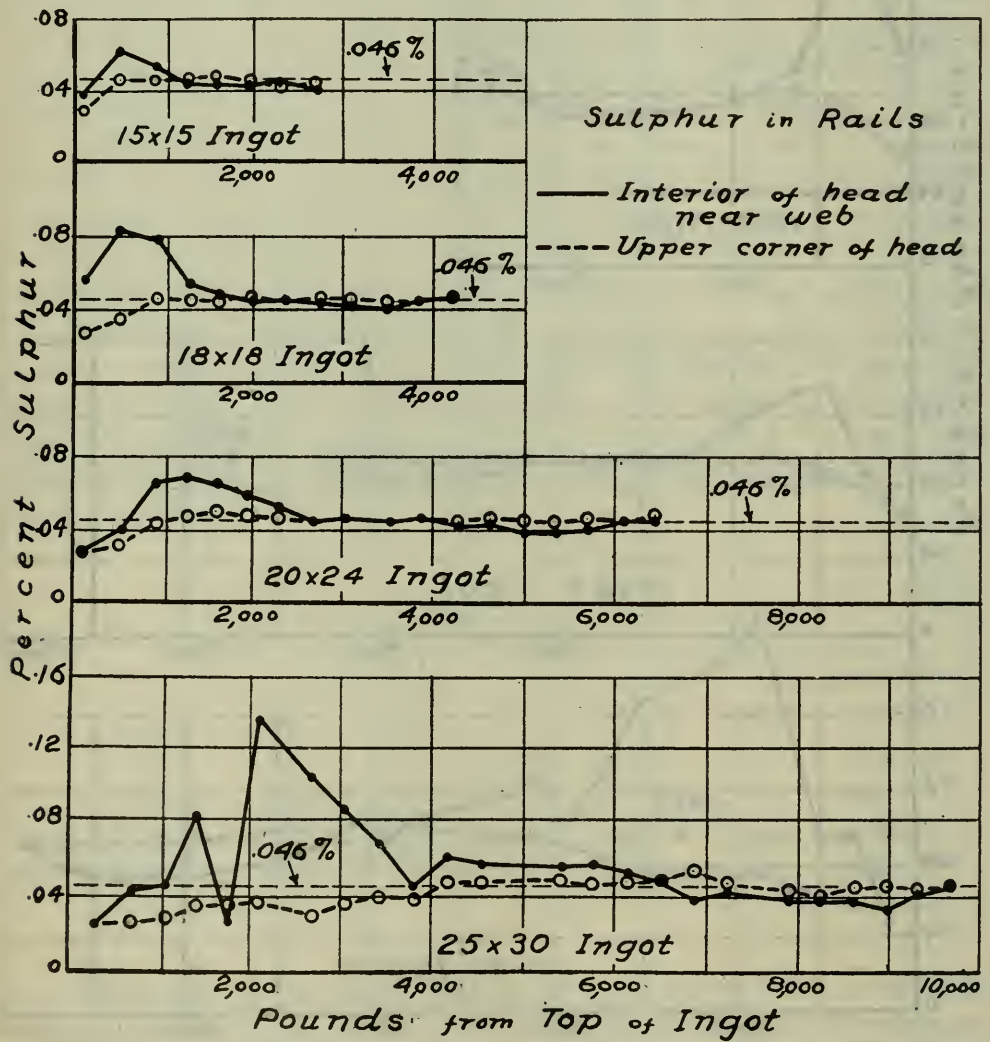


FIG. 25—DIAGRAMS OF SULPHUR IN RAILS.

A comparison of the analyses from the upper corner of the head and from the edge of the flange shows that in the great majority of cases the results are closely alike, and it would seem unnecessary to take borings from the flange except for some special purpose.

RAIL ETCHINGS.

Sections were cut each eleven feet along the rail bars and etched with a concentrated solution of copper ammonium or copper potassium chloride. Photographs of the etched sections are reproduced in figures as follows:

15x15 Ingot—Figures 26 to 33, inclusive.
18x18 Ingot—Figures 34 to 45, inclusive.
20x24 Ingot—Figures 46 to 63, inclusive.
25x30 Ingot—Figures 64 to 87, inclusive.

It will be noted that the sections from the upper part of the ingot show streaks and spots which correspond with the condition of sponginess found in the ingot. There may also be a dark area or "dark core" in the interior of the section corresponding with the region of strong segregation found in the ingot. The sections from the lower part of the ingot also show a core, but of lighter color, or a "light core," which corresponds to the region of negative segregation in the ingot found by analysis. This light core shows up most prominently in the largest ingot. The figures showing the etched sections from the smaller ingots do not show the light core prominently, and in fact it does not always show well in the original etching.

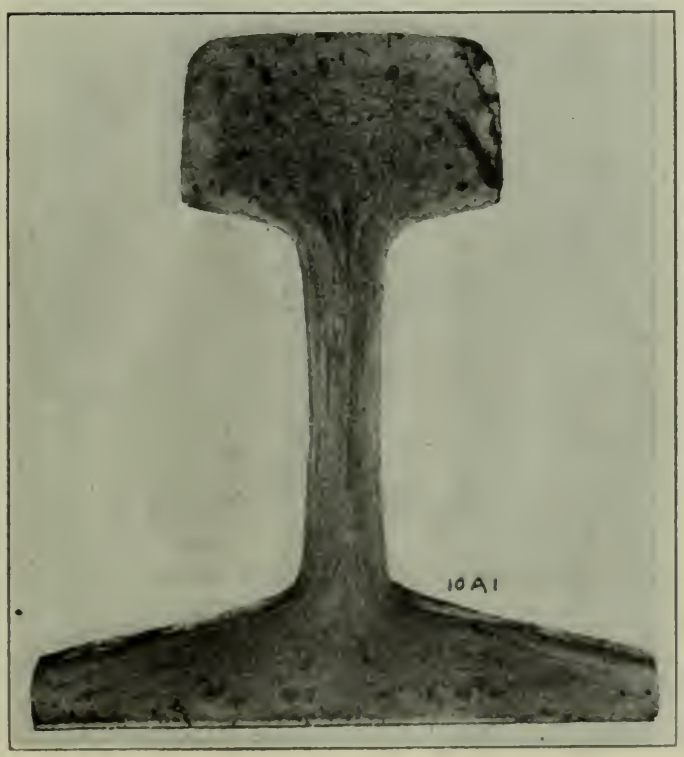


FIG. 26—ETCHED SECTION 1 FT. FROM TOP END OF A RAIL, 15x15 INGOT.

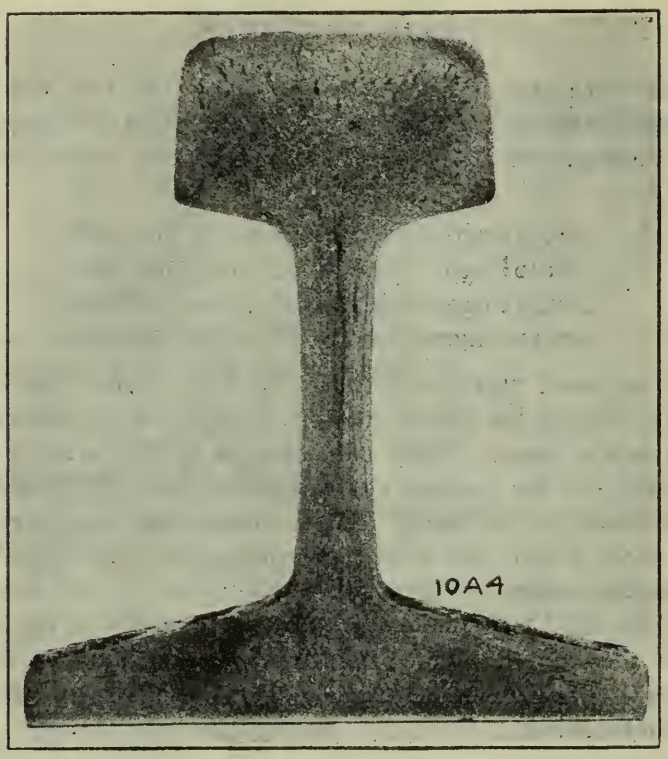


FIG. 27—ETCHED SECTION 12 FT. FROM TOP END OF A RAIL, 15x15 INGOT.

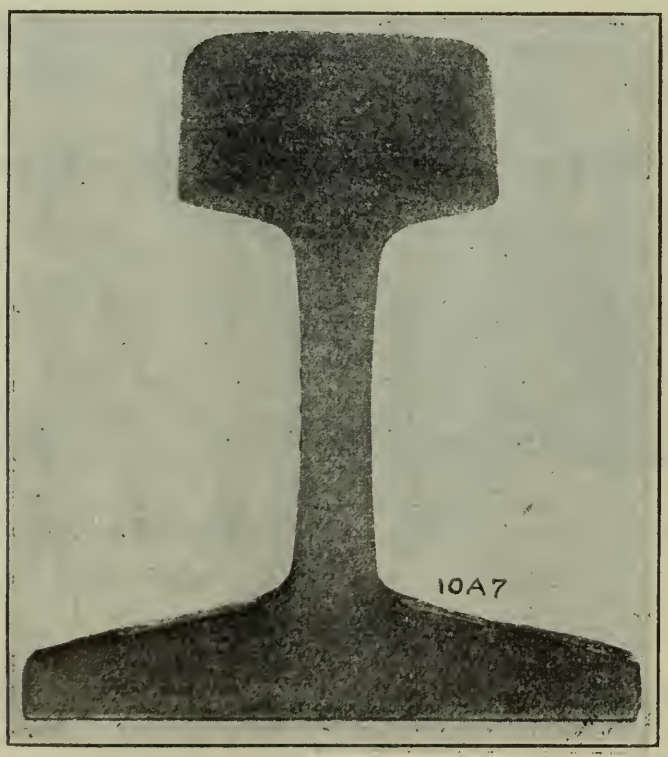


FIG. 28—ETCHED SECTION, 23 FT. FROM TOP END OF A RAIL, 15x15 INGOT

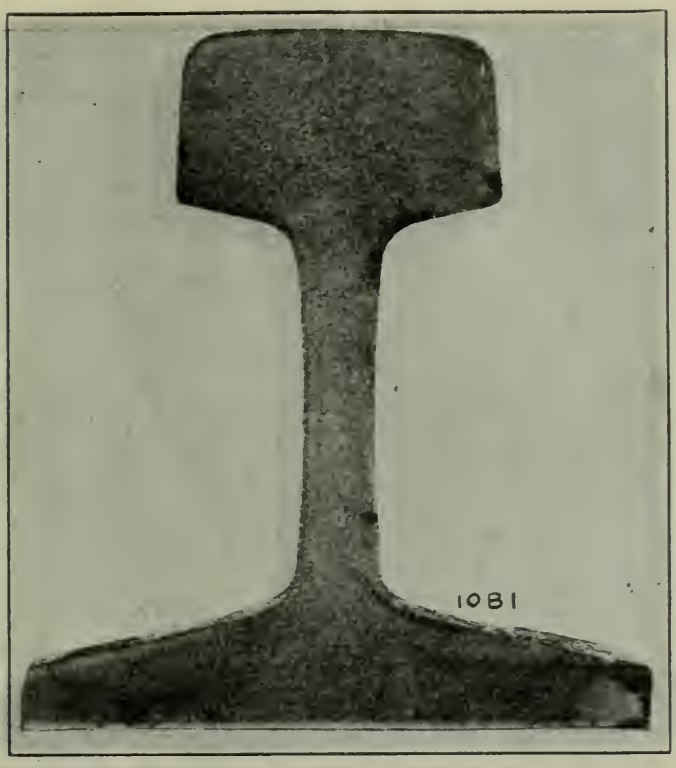


FIG. 29—ETCHED SECTION 1 FT. FROM TOP END OF B RAIL, 15X15 INGOT.

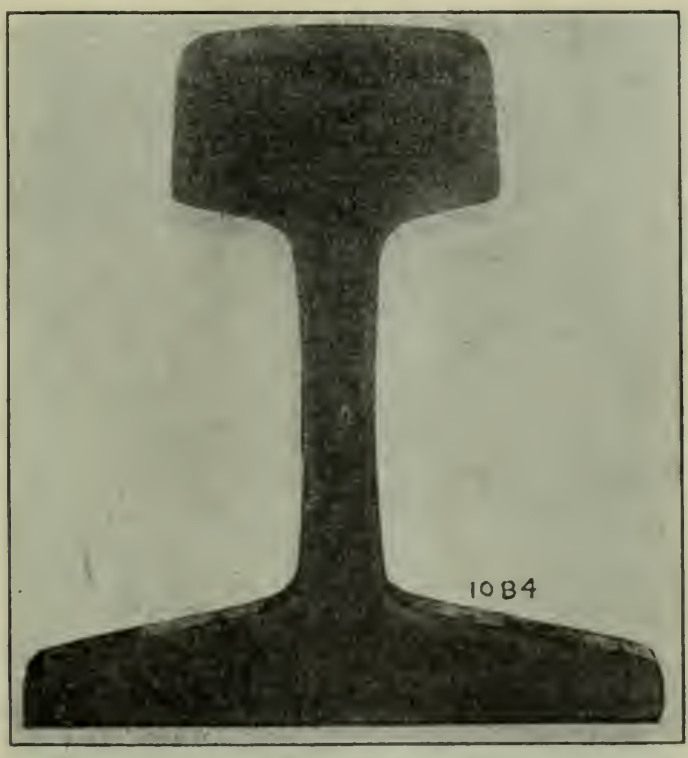


FIG. 30—ETCHED SECTION, 12 FT. FROM TOP END OF B RAIL, 15X15 INGOT.

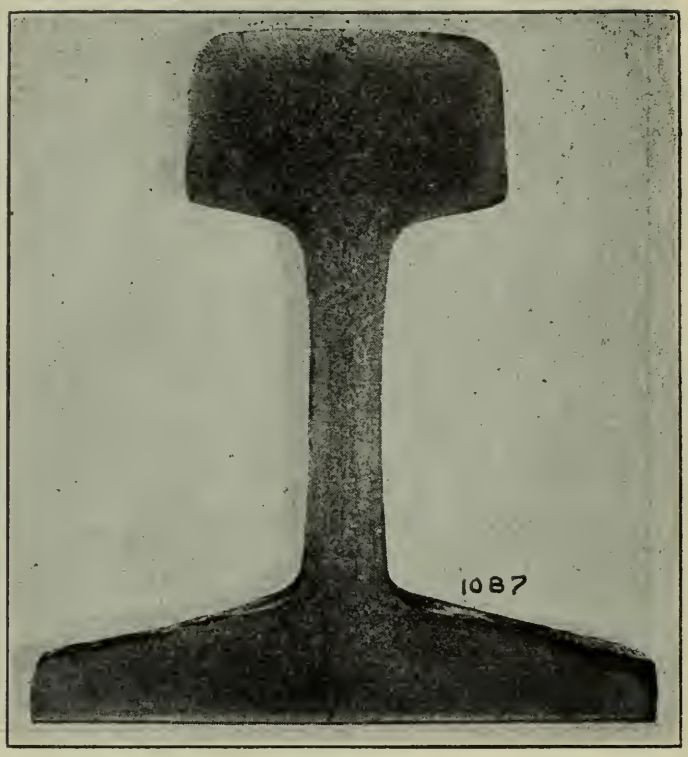


FIG. 31—ETCHED SECTION, 23 FT. FROM TOP END OF B RAIL, 15X15 INGOT

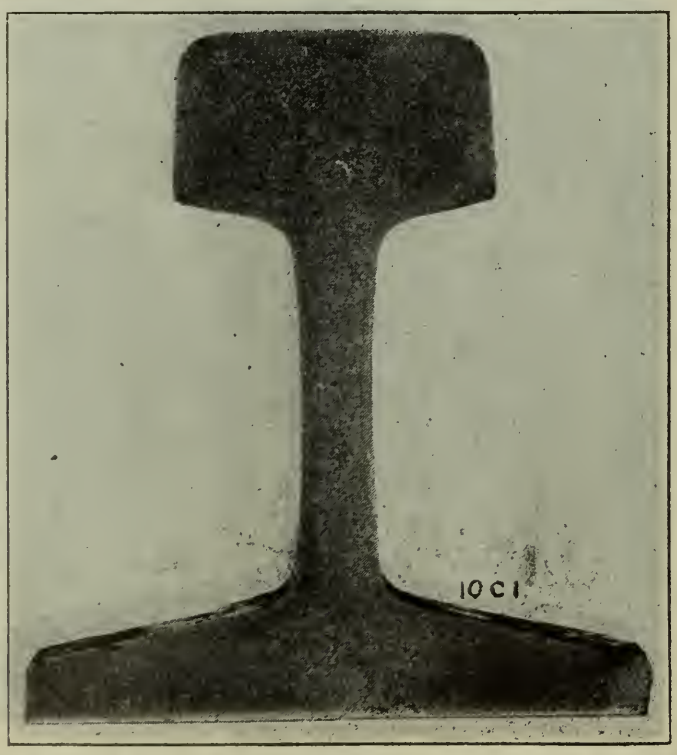


FIG. 32—ETCHED SECTION, 1 FT. FROM TOP END OF C RAIL, 15X15 INGOT.

FIG. 33—ETCHED SECTION, 12 FT. FROM TOP END OF C RAIL, 15X15 INGOT.

FIG. 34—ETCHED SECTION, 1 FT. FROM TOP END OF A RAIL, 18X18 INGOT.

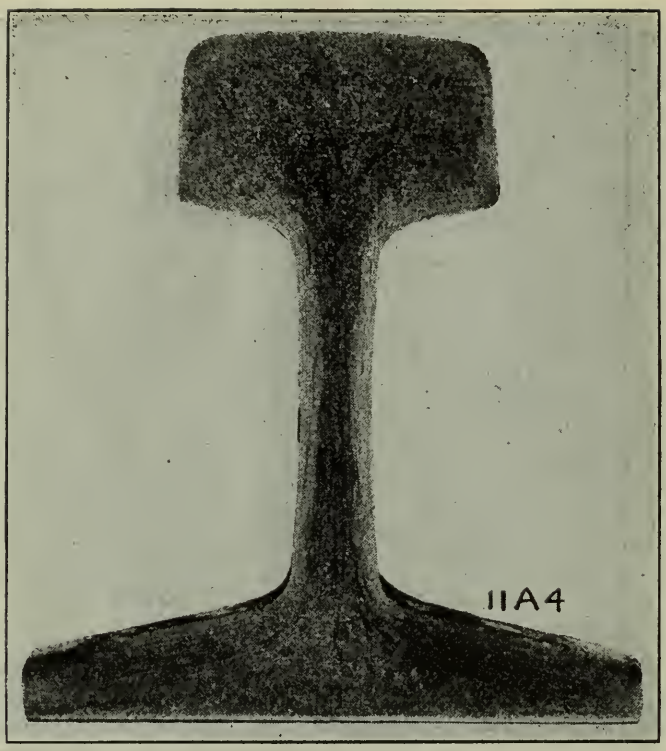


FIG. 35—ETCHED SECTION, 12 FT. FROM TOP END OF A RAIL, 18x18 INGOT.

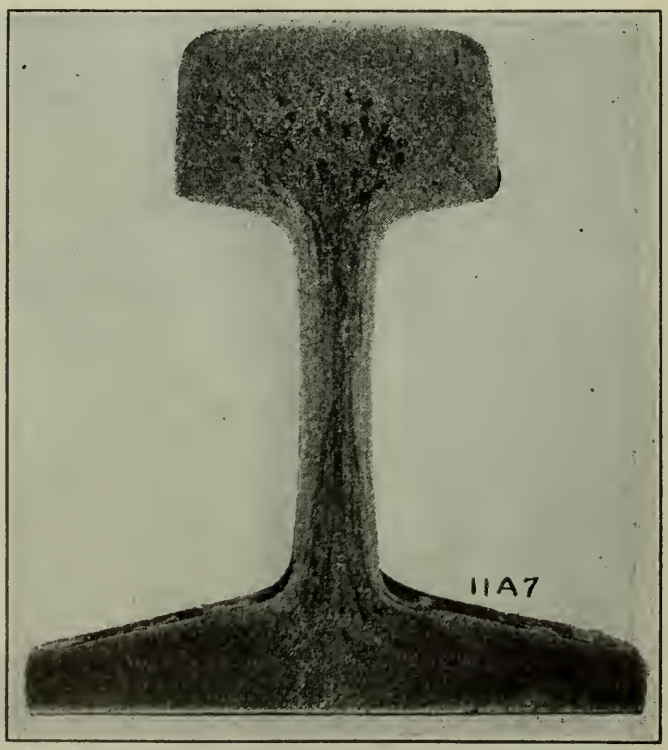


FIG. 36—ETCHED SECTION, 23 FT. FROM TOP END OF A RAIL, 18x18 INGOT.

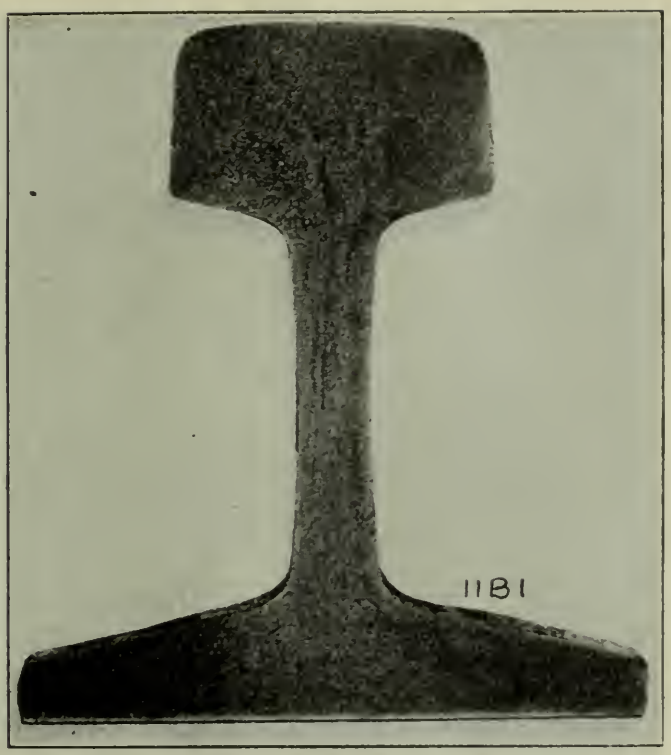


FIG. 37—ETCHED SECTION, 1 FT. FROM TOP END OF B RAIL, 18x18 INGOT.

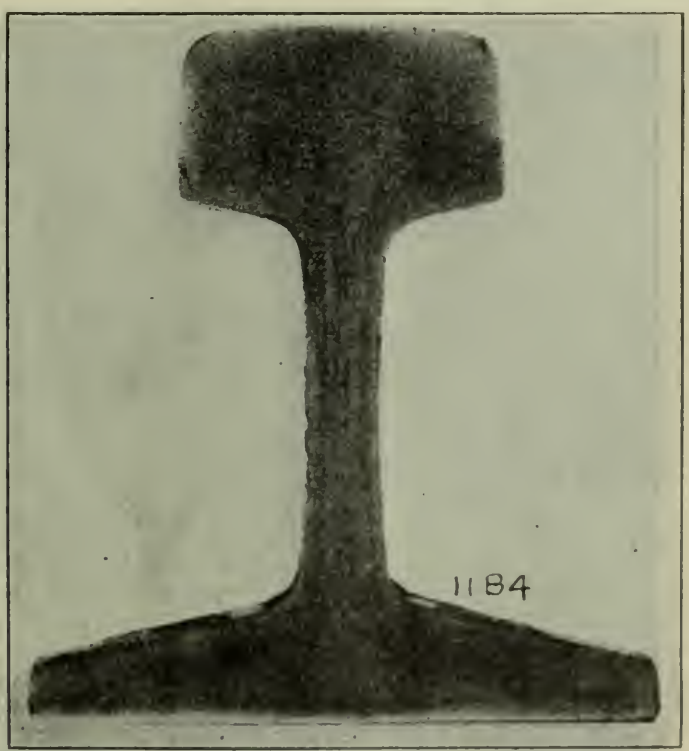


FIG. 38—ETCHED SECTION, 12 FT. FROM TOP END OF B RAIL, 18x18 INGOT.

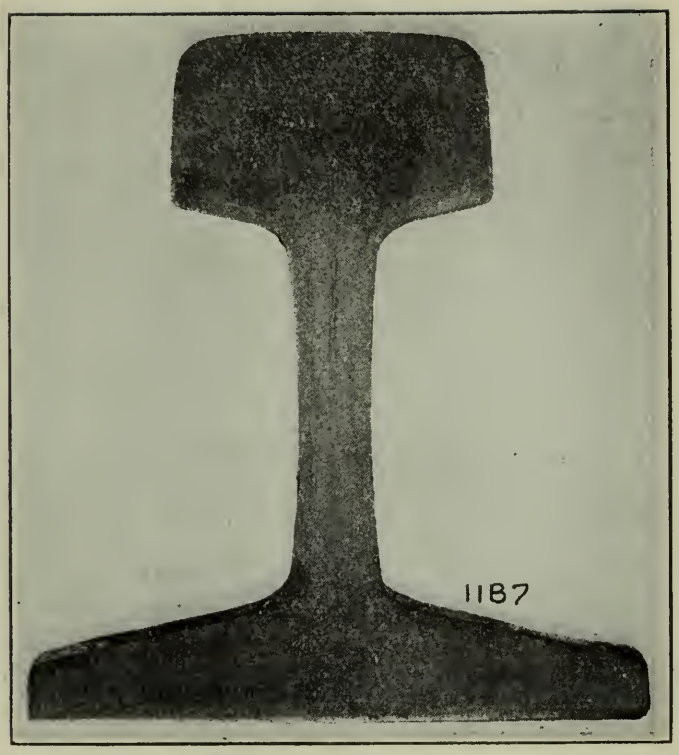


FIG. 39—ETCHED SECTION, 23 FT. FROM TOP END OF B RAIL, 18x18 INGOT.

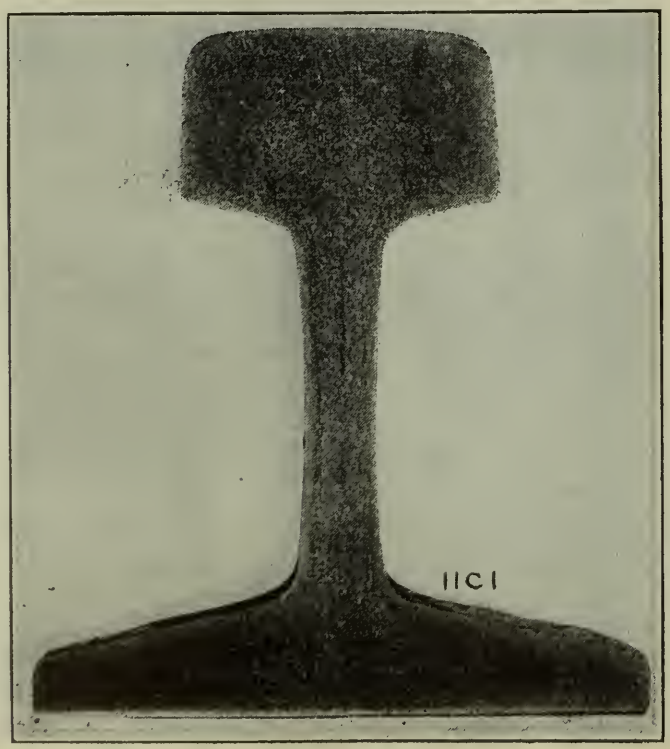


FIG. 40—ETCHED SECTION, 1 FT. FROM TOP END OF C RAIL, 18x18 INGOT.

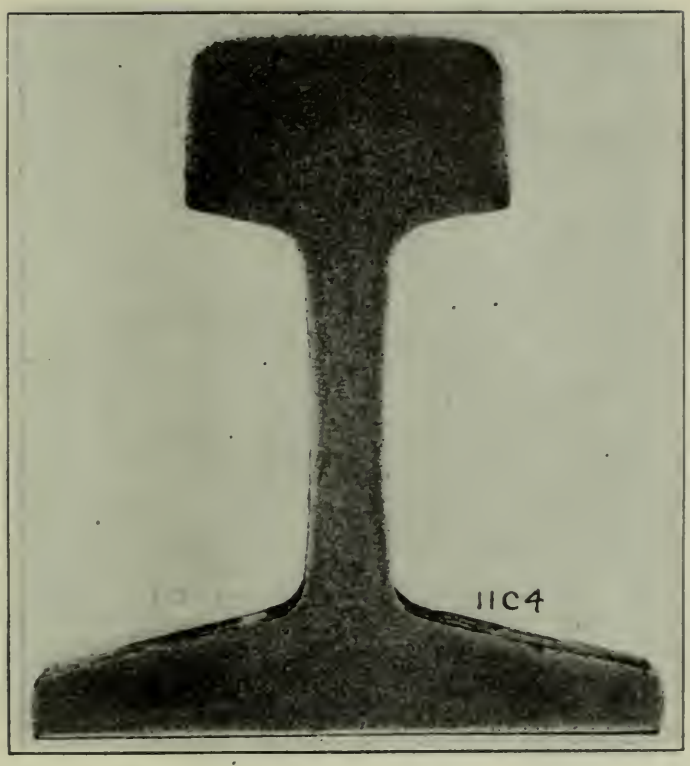


FIG. 41—ETCHED SECTION, 12 FT. FROM TOP END OF C RAIL, 18x18 INGOT.

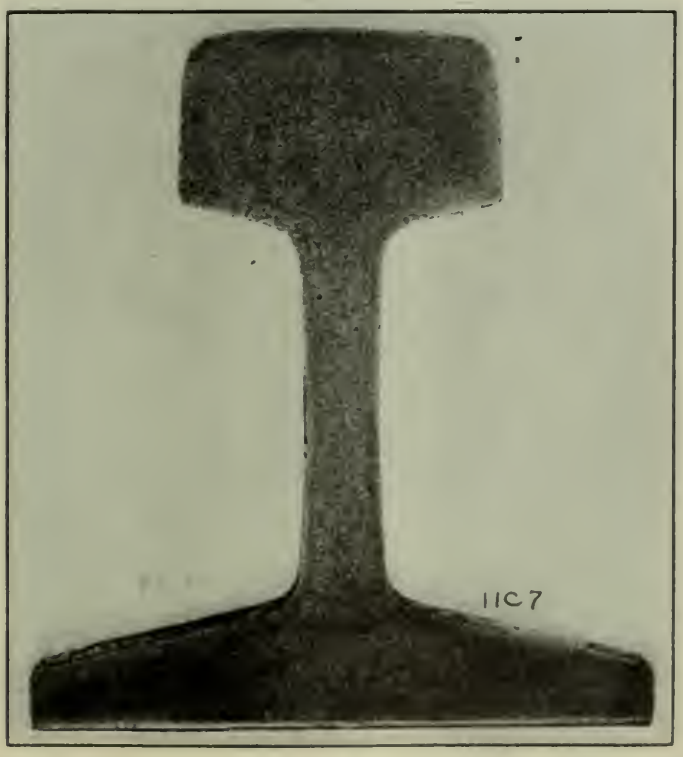


FIG. 42—ETCHED SECTION, 23 FT. FROM TOP END OF C RAIL, 18x18 INGOT

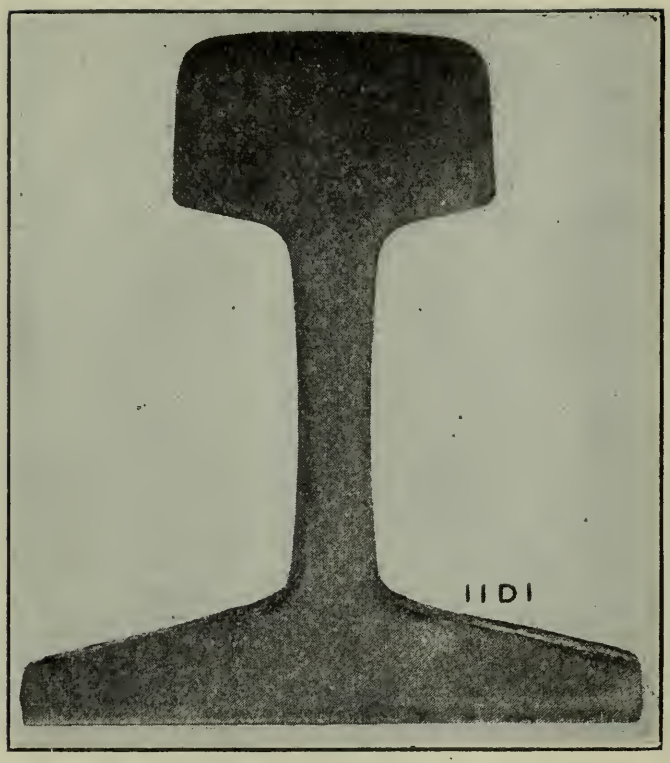


FIG. 43—ETCHED SECTION, 1 FT. FROM TOP END OF D RAIL, 18x18 INGOT.

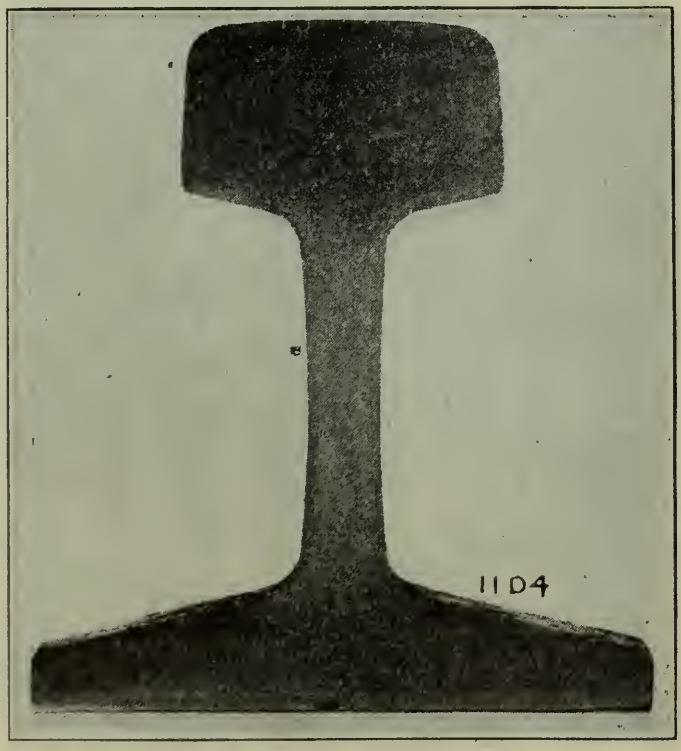


FIG. 44—ETCHED SECTION, 12 FT. FROM TOP END OF D RAIL, 18x18 INGOT.

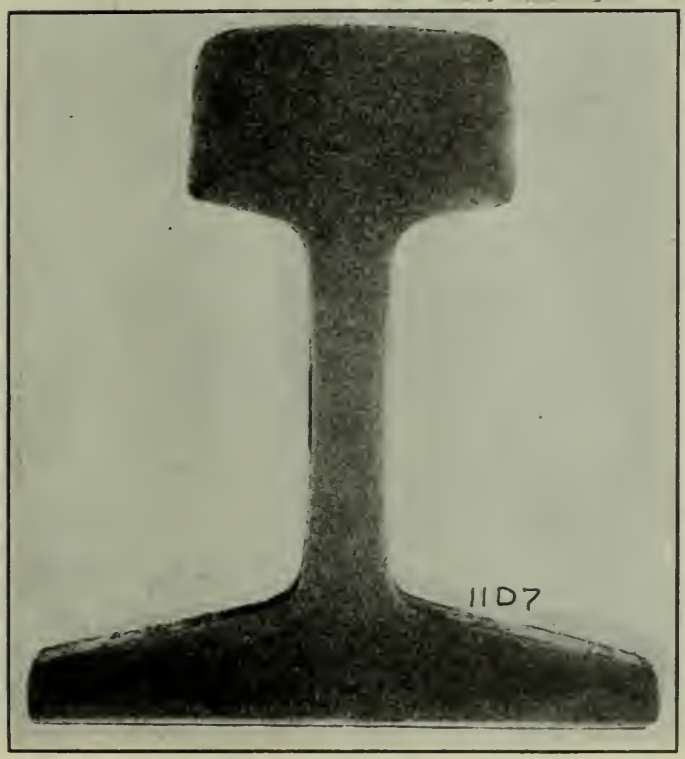


FIG. 45—ETCHED SECTION, 23 FT. FROM TOP END OF D RAIL, 18x18 INGOT.

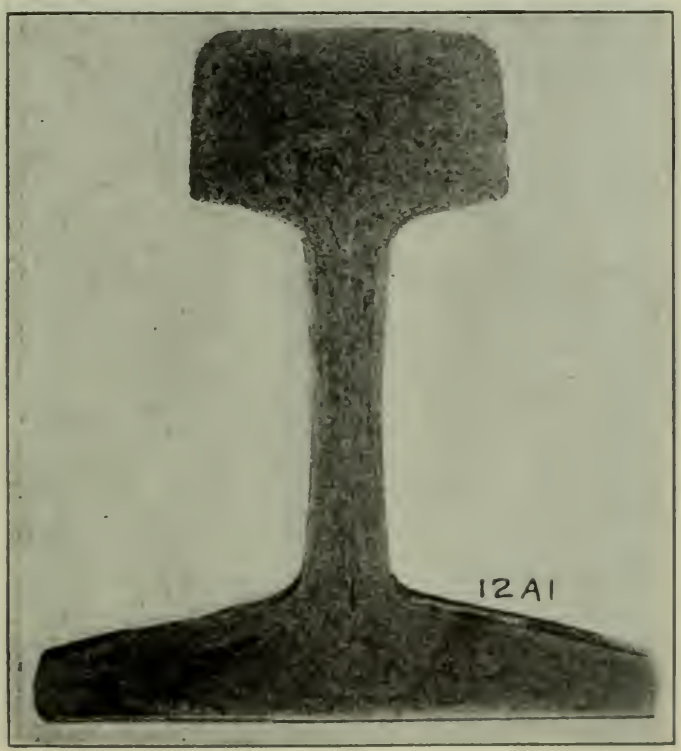


FIG. 46—ETCHED SECTION, 1 FT. FROM TOP END OF A RAIL, 20x24 INGOT.

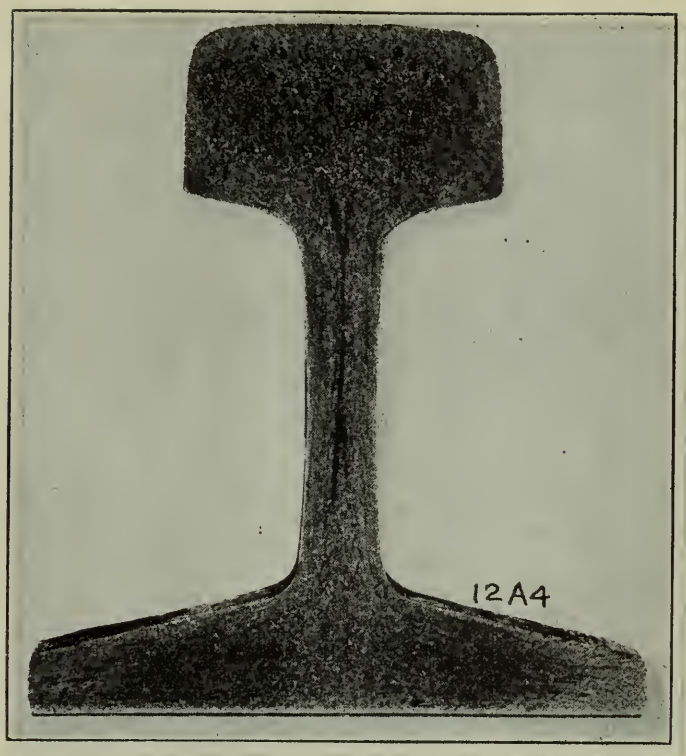


FIG. 47—ETCHED SECTION, 12 FT. FROM TOP END OF A RAIL, 20X24 INGOT.

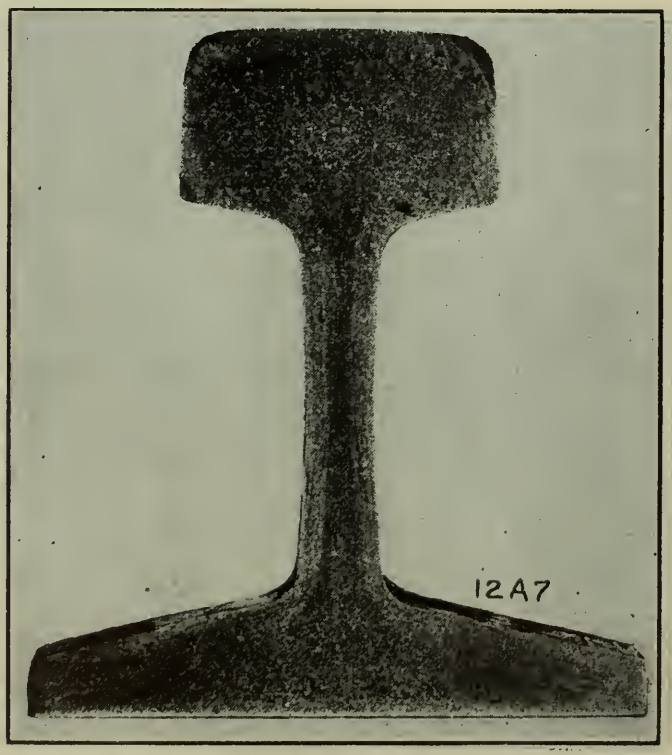


FIG. 48—ETCHED SECTION, 23 FT. FROM TOP END OF A RAIL, 20X24 INGOT.

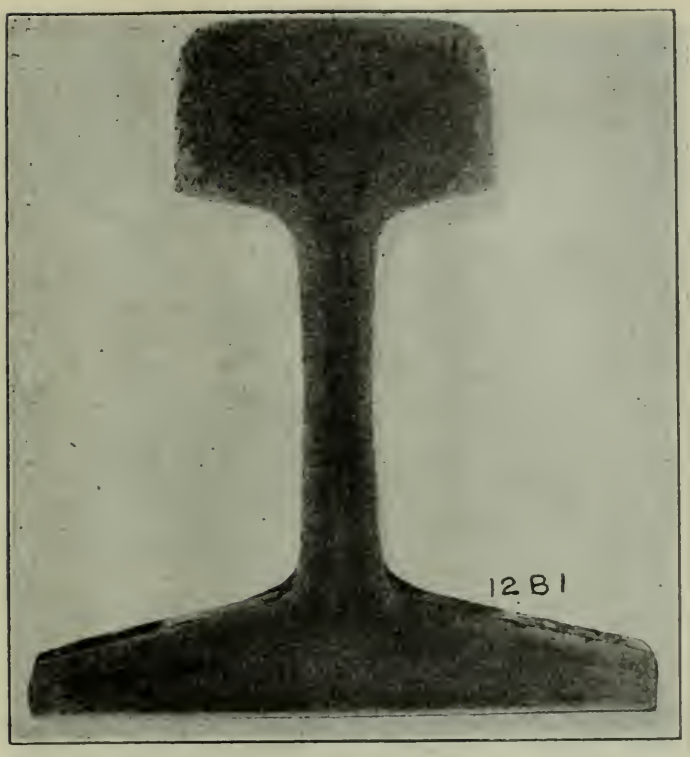


FIG. 49—ETCHED SECTION, 1 FT. FROM TOP END OF B RAIL, 20X24 INGOT.

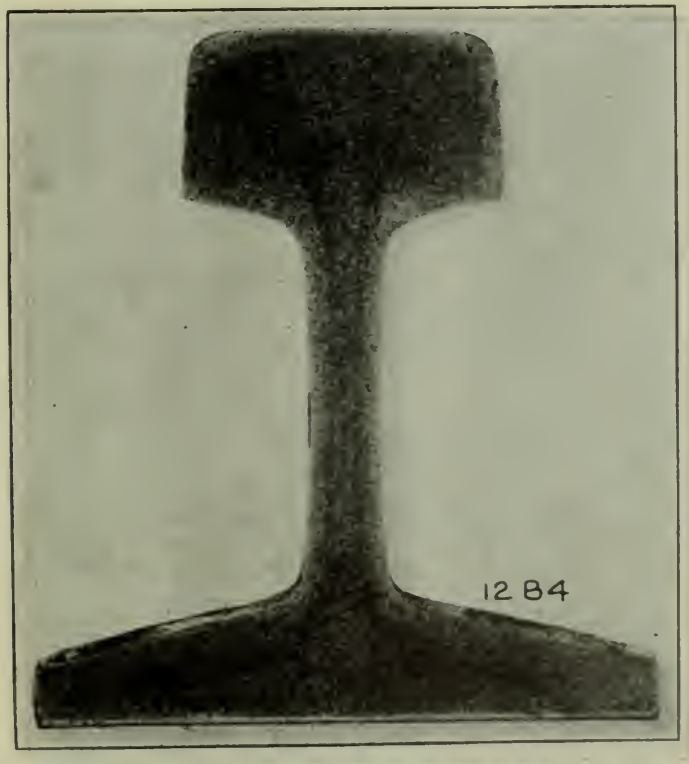


FIG. 50—ETCHED SECTION, 12 FT. FROM TOP END OF B RAIL, 20X24 INGOT.

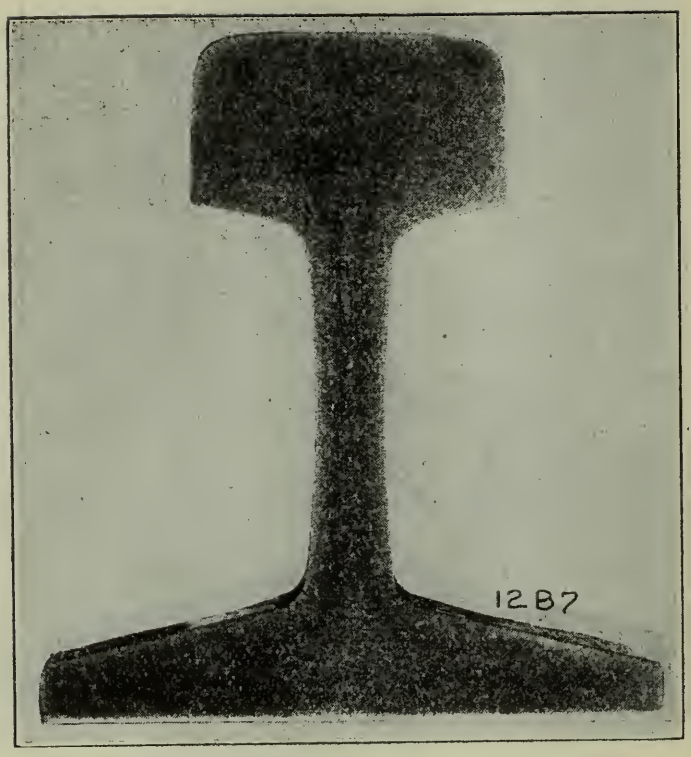


FIG. 51—ETCHED SECTION, 23 FT. FROM TOP END OF B RAIL, 20X24 INGOT.

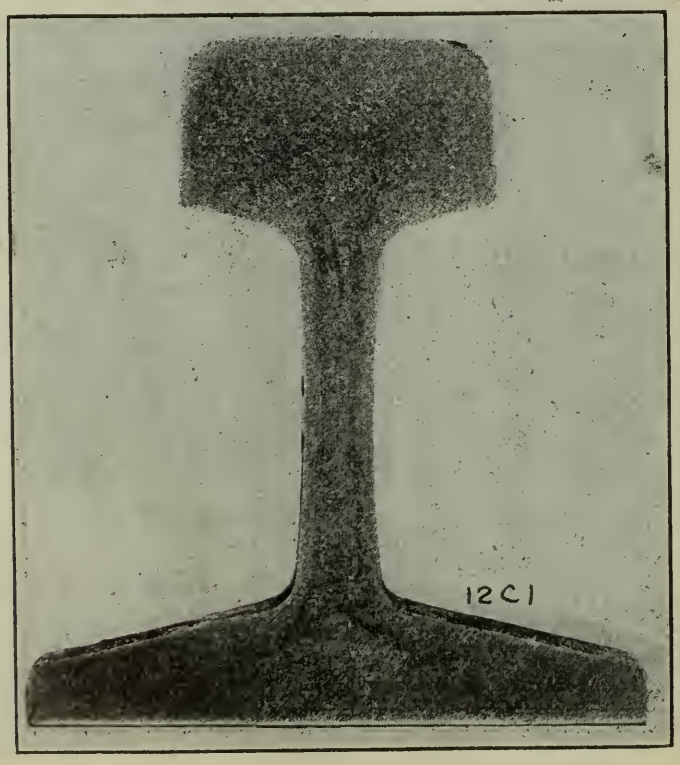


FIG. 52—ETCHED SECTION, 1 FT. FROM TOP END OF C RAIL, 20X24 INGOT.

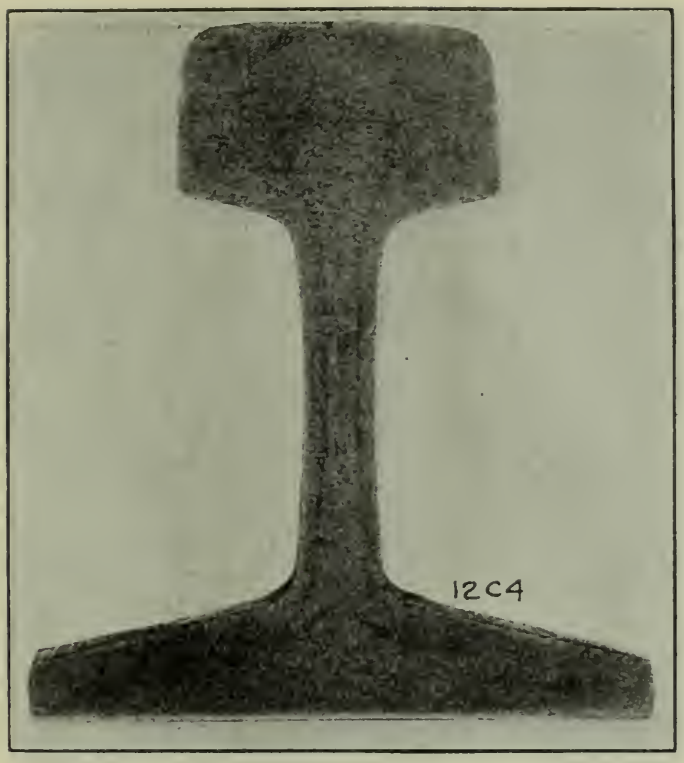


FIG. 53—ETCHED SECTION, 12 FT. FROM TOP END OF C RAIL, 20X24 INGOT.

FIG. 54—ETCHED SECTION, 23 FT. FROM TOP END OF C RAIL, 20X24 INGOT.

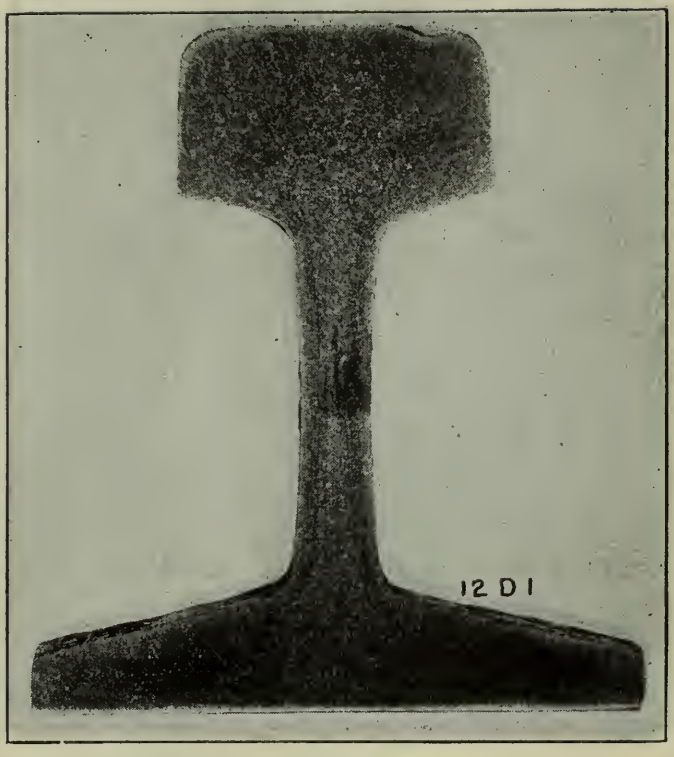


FIG. 55—ETCHED SECTION, 1 FT. FROM TOP END OF D RAIL, 20X24 INGOT.

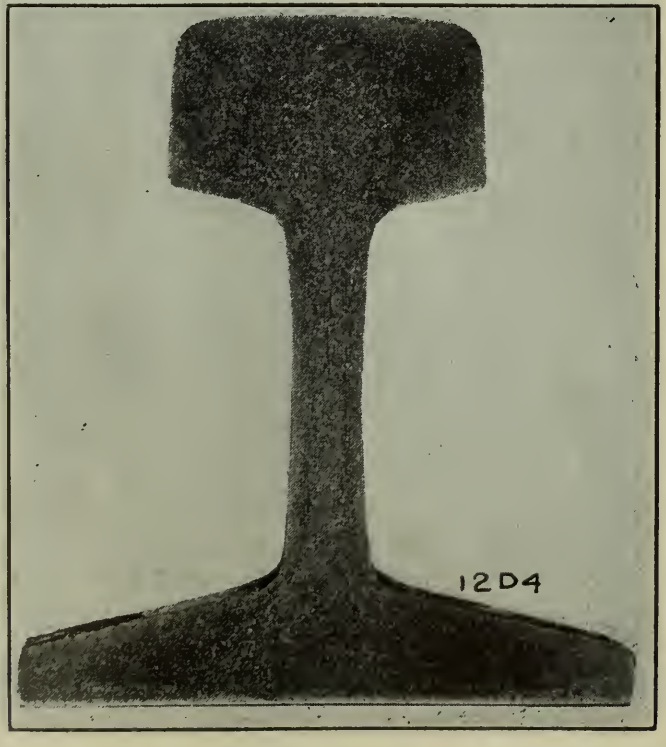


FIG. 56—ETCHED SECTION, 12 FT. FROM TOP END OF D RAIL, 20X24 INGOT.

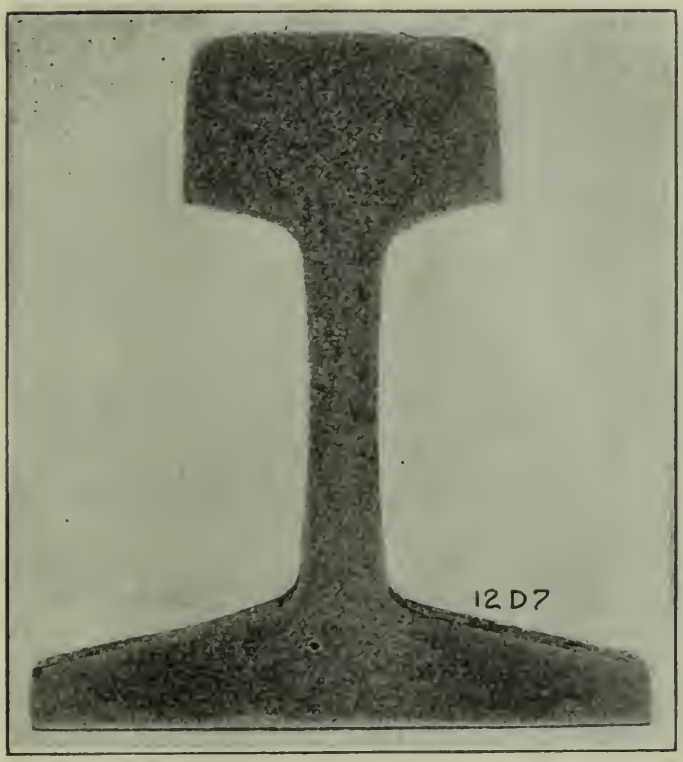


FIG. 57—ETCHED SECTION, 23 FT. FROM TOP END OF D RAIL, 20X24 INGOT.

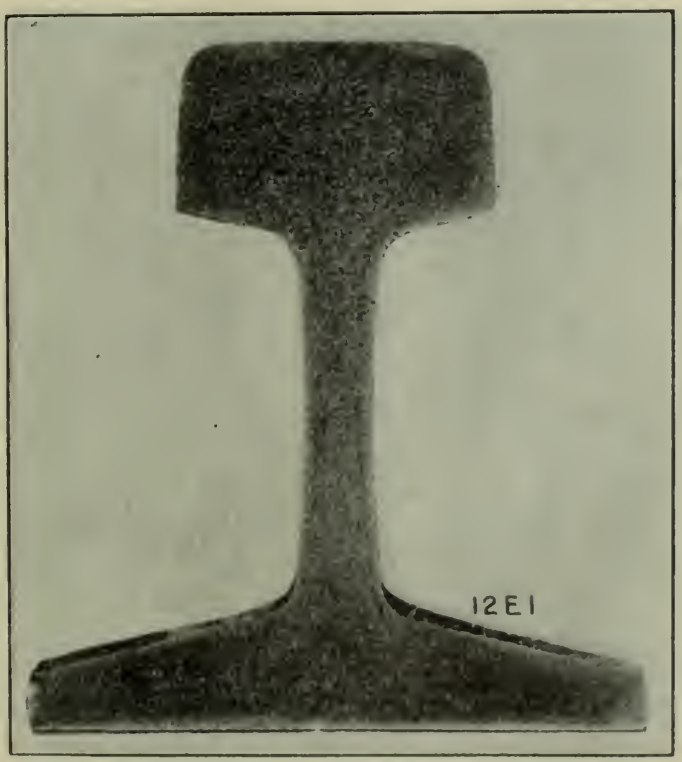


FIG. 58—ETCHED SECTION, 1 FT. FROM TOP END OF E RAIL, 20X24 INGOT.

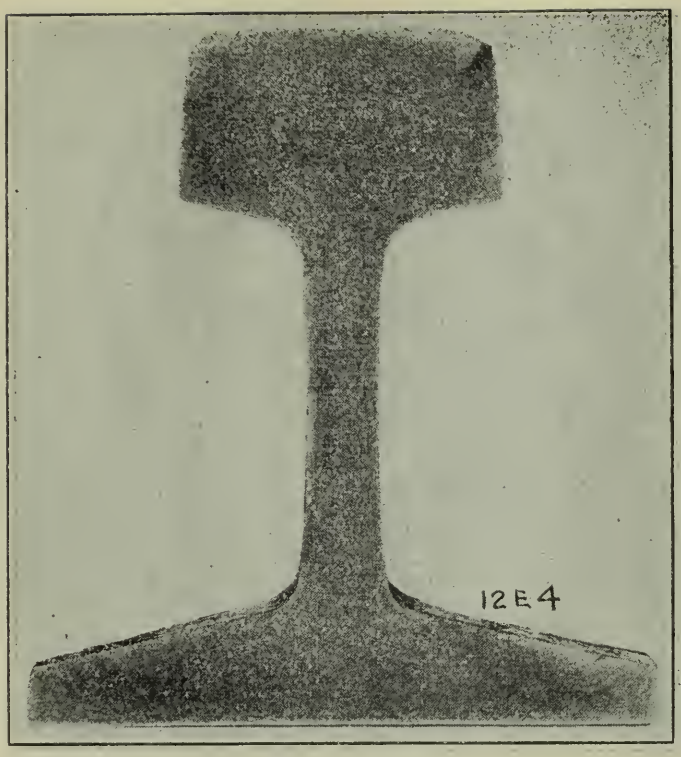


FIG. 59—ETCHED SECTION, 12 FT. FROM TOP END OF E RAIL, 20X24 INGOT.

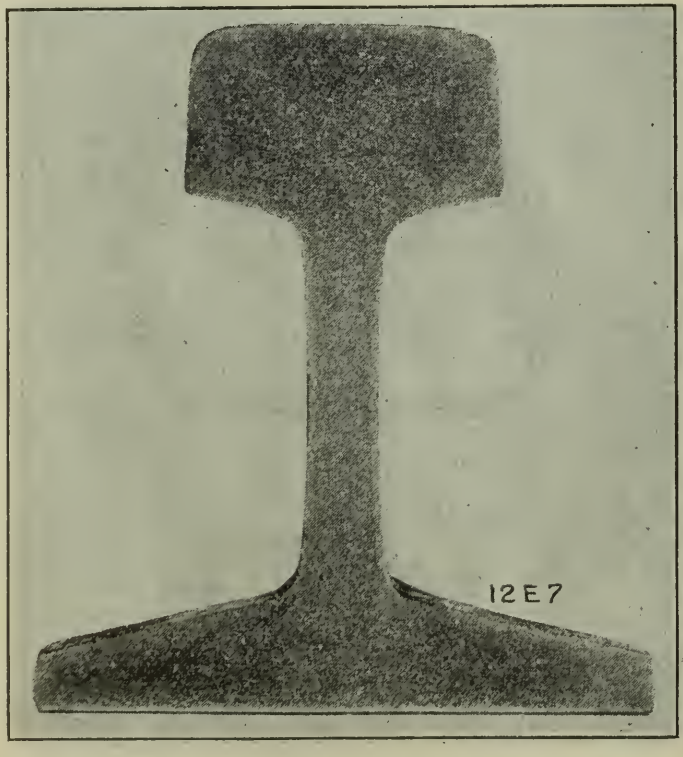


FIG. 60—ETCHED SECTION, 23 FT. FROM TOP END OF E RAIL, 20X24 INGOT.

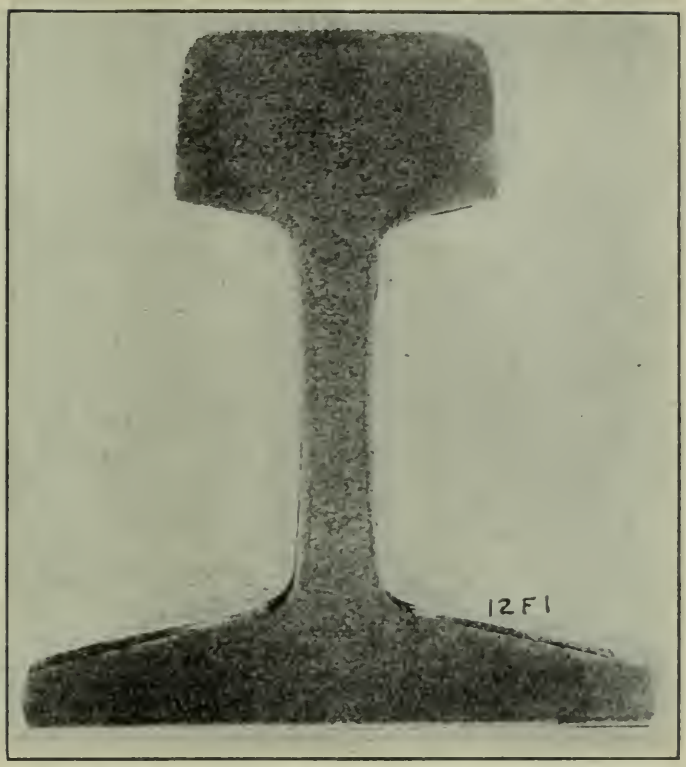


FIG. 61—ETCHED SECTION, 1 FT. FROM TOP END OF F RAIL, 20X24 INGOT.

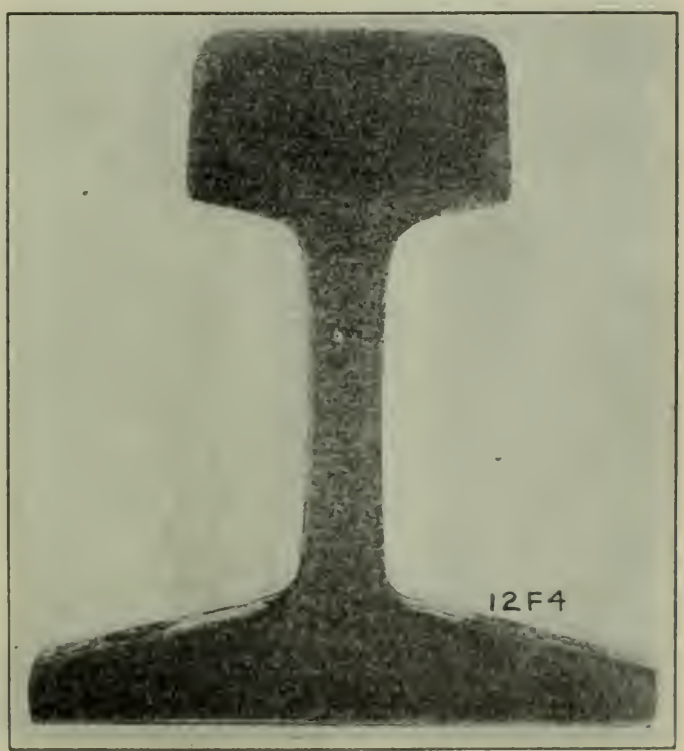


FIG. 62—ETCHED SECTION, 12 FT. FROM TOP END OF F RAIL, 20X24 INGOT.

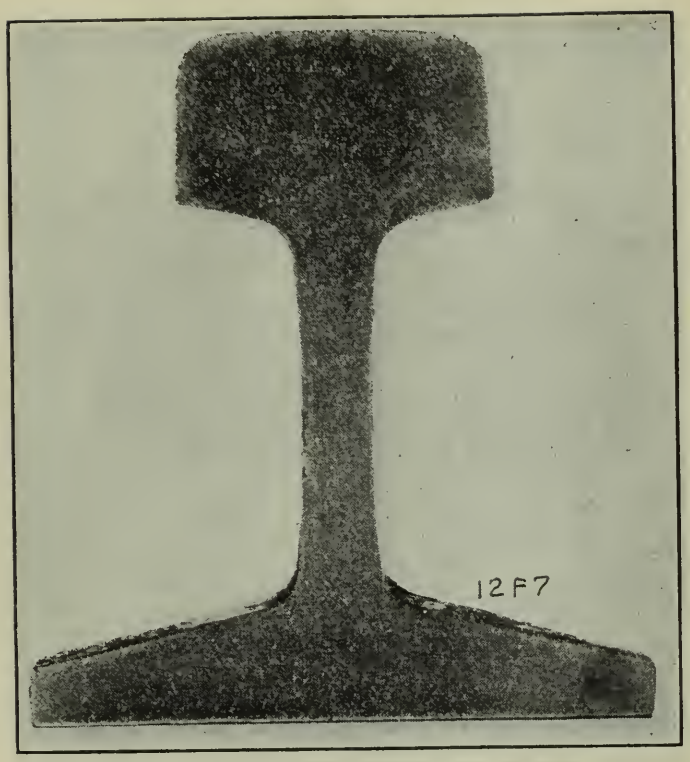


FIG. 63—ETCHED SECTION, 23 FT. FROM TOP END OF F RAIL, 20X24 INGOT.

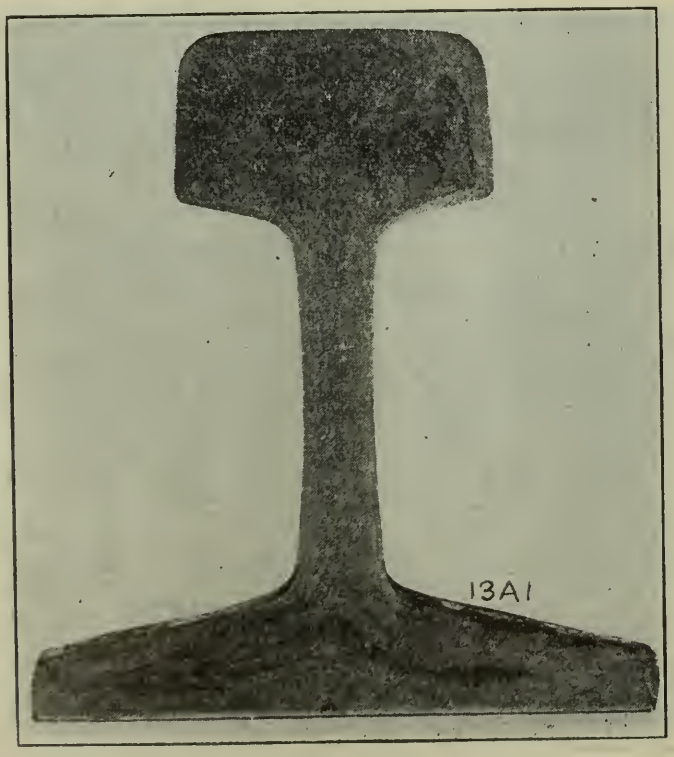


FIG. 64—ETCHED SECTION, 1 FT. FROM TOP END OF A RAIL, 25X30 INGOT.

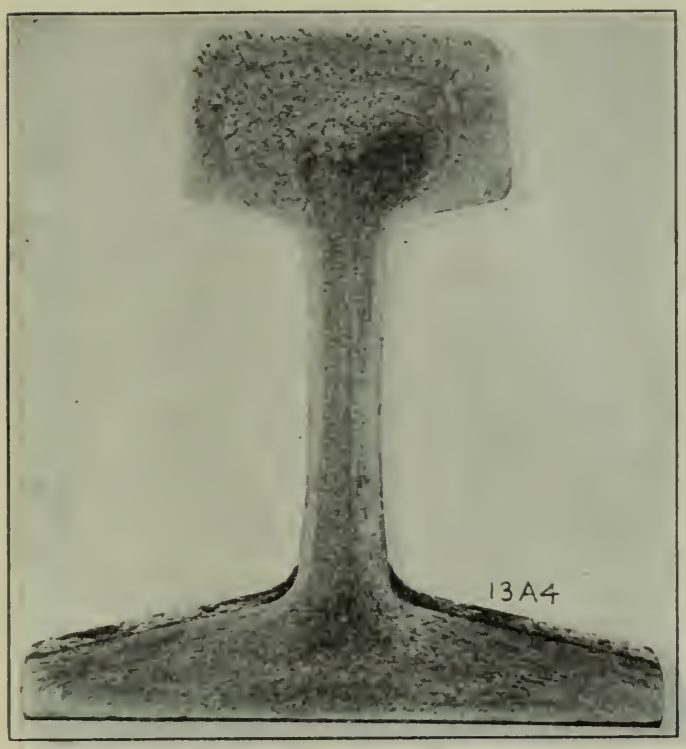


FIG. 65—ETCHED SECTION, 12 FT. FROM TOP END OF A RAIL, 25X30 INGOT

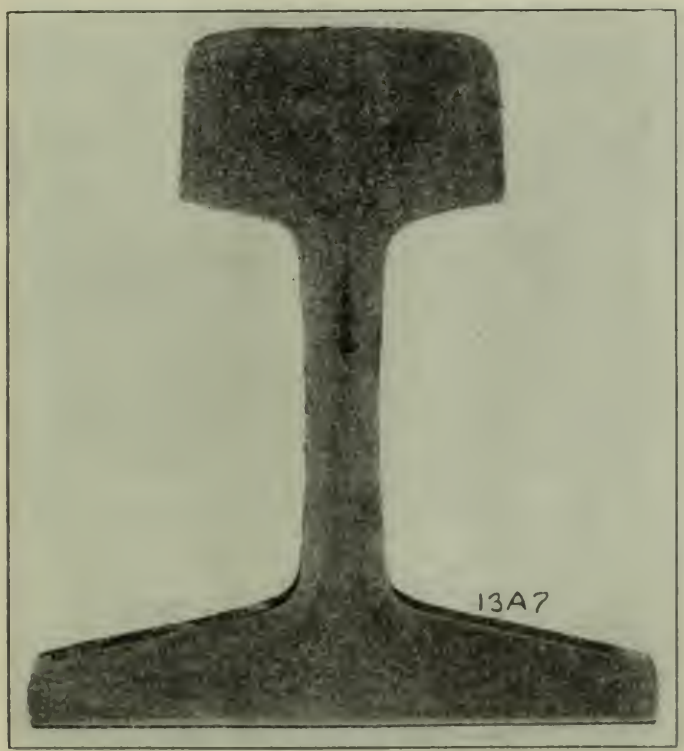


FIG. 66—ETCHED SECTION, 23 FT. FROM TOP END OF A RAIL, 25X30 INGOT.

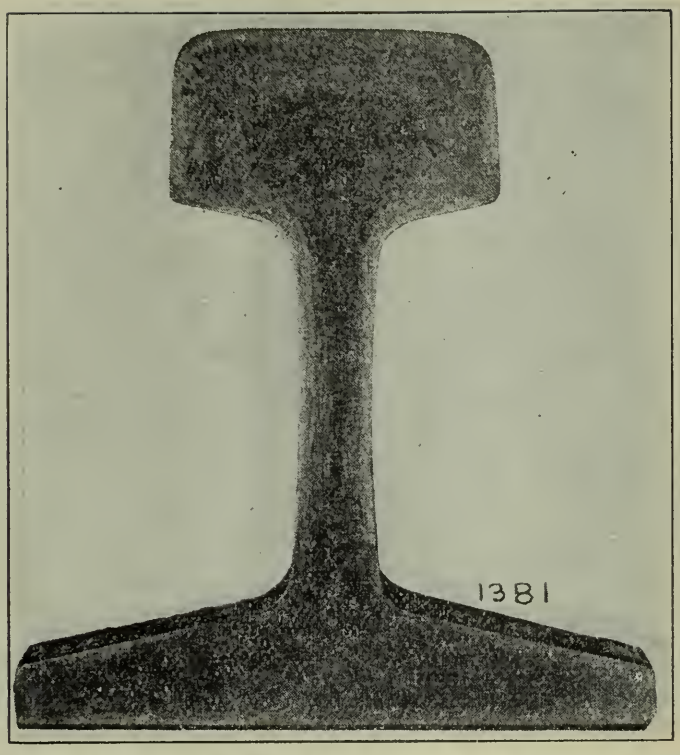


FIG. 67—ETCHED SECTION, 1 FT. FROM TOP END OF B RAIL, 25x30 INGOT.

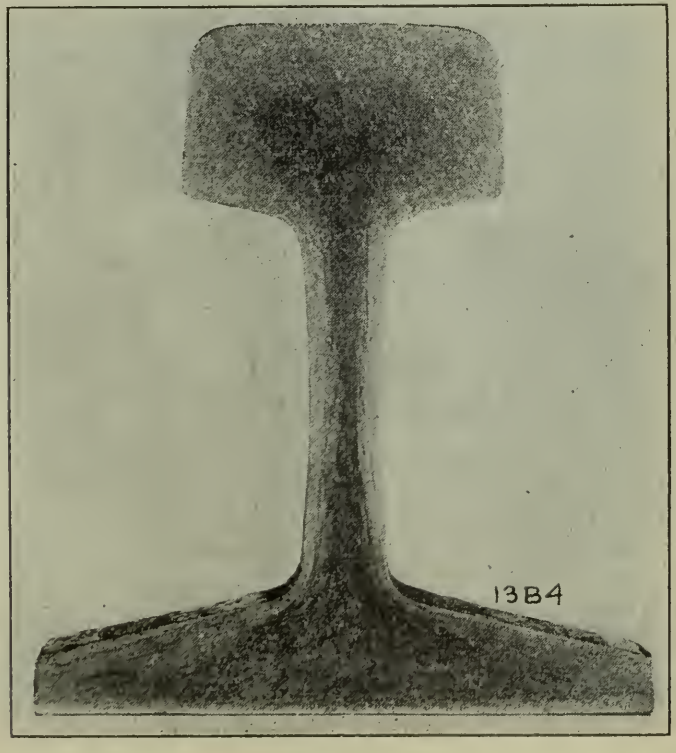


FIG. 68—ETCHED SECTION, 12 FT. FROM TOP END OF B RAIL, 25x30 INGOT.

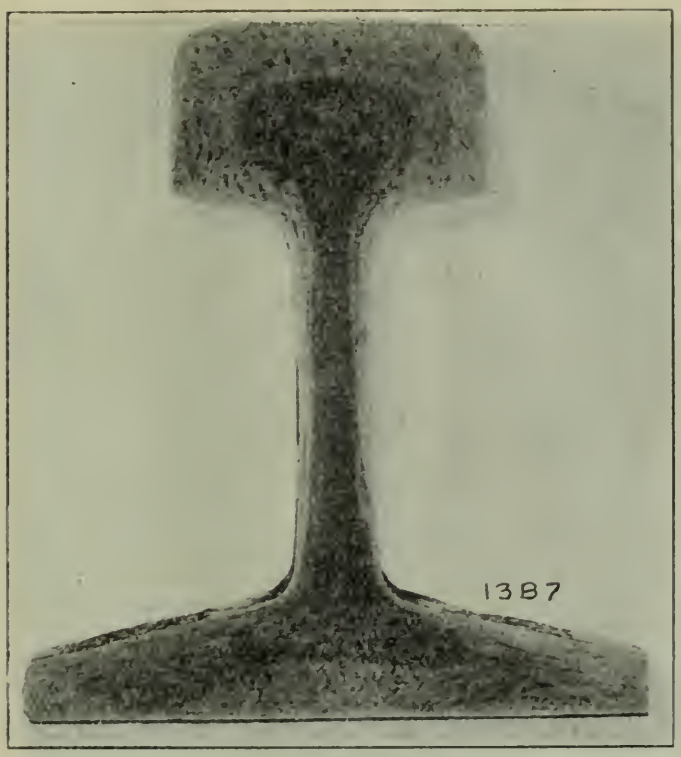


FIG. 69—ETCHED SECTION, 23 FT. FROM TOP END OF B RAIL, 25X30 INGOT.

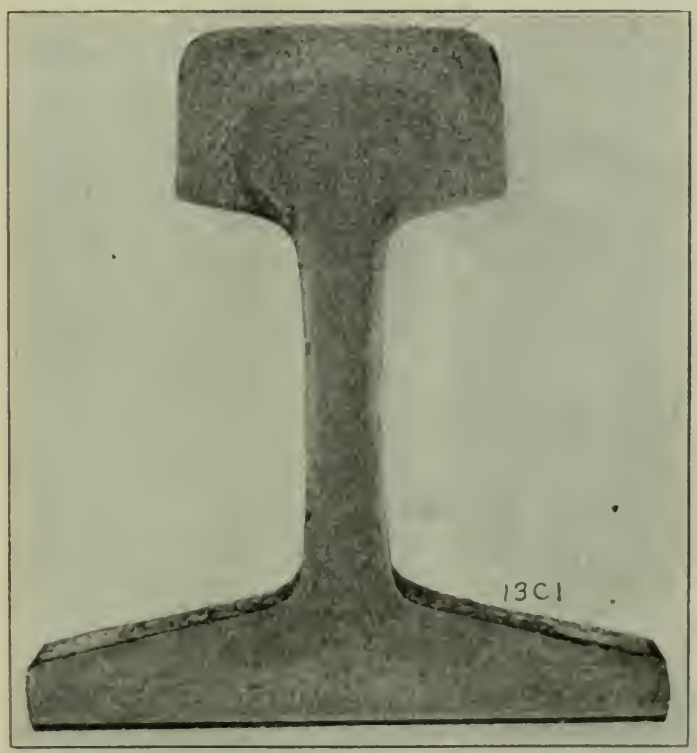


FIG. 70—ETCHED SECTION, 1 FT. FROM TOP END OF C RAIL, 25X30 INGOT.

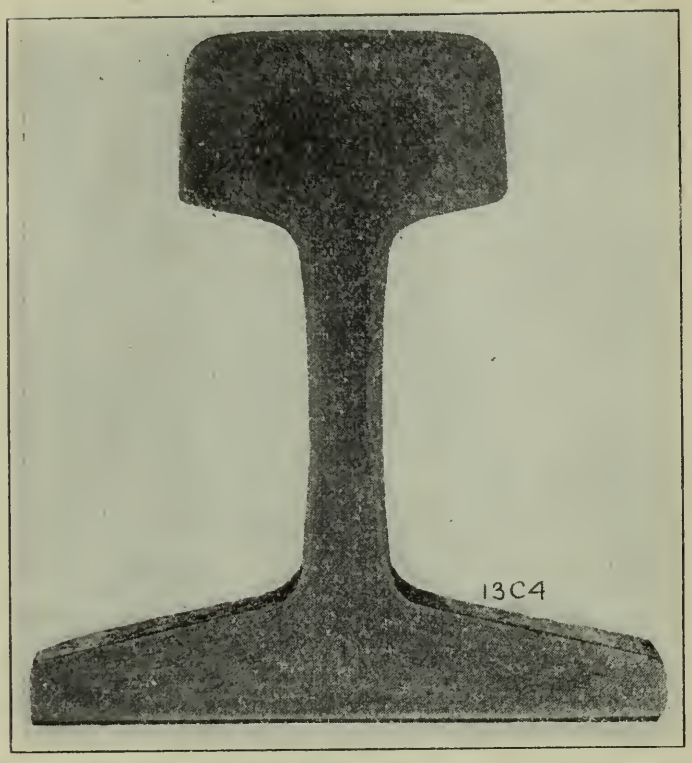


FIG. 71—ETCHED SECTION, 12 FT. FROM TOP END OF C RAIL, 25X30 INGOT.

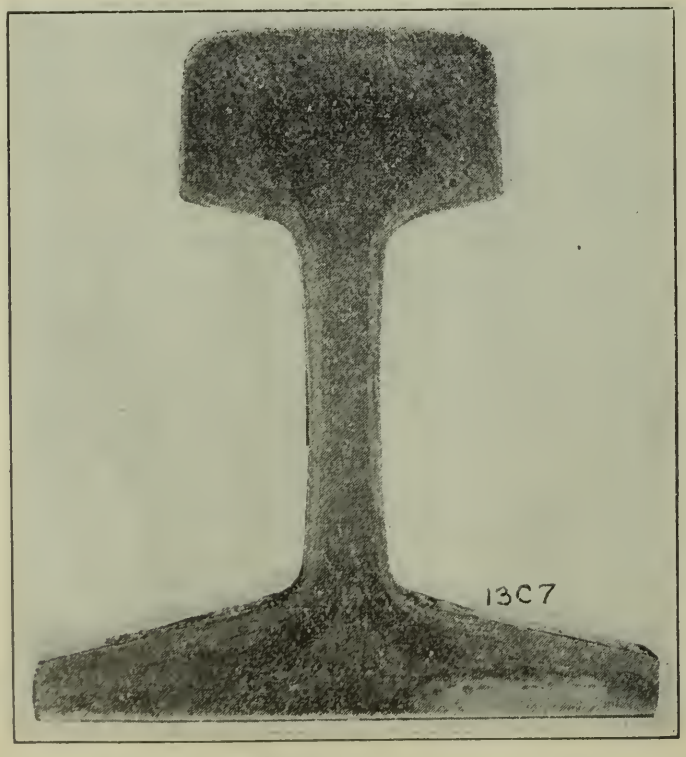


FIG. 72—ETCHED SECTION, 23 FT. FROM TOP END OF C RAIL, 25X30 INGOT.

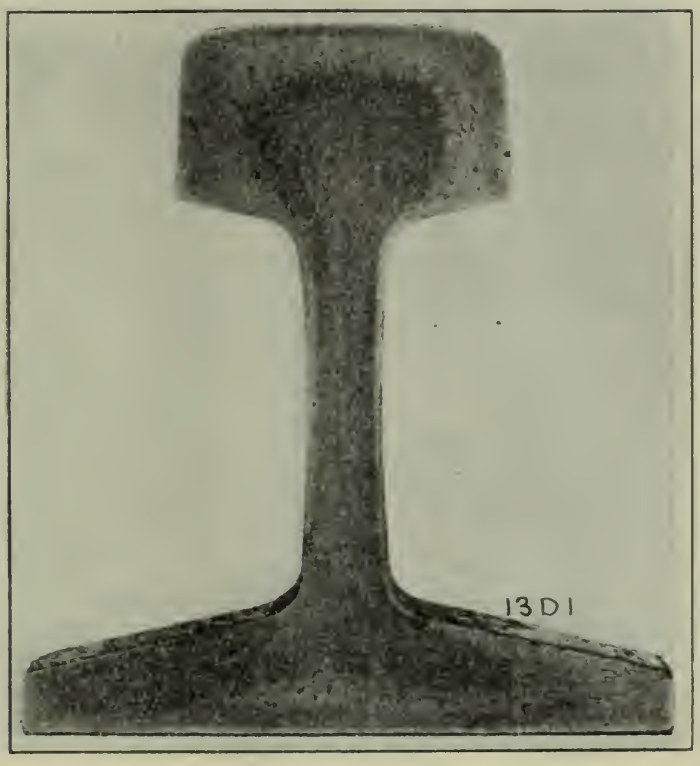


FIG. 73—ETCHED SECTION, 1 FT. FROM TOP END OF D RAIL, 25X30 INGOT.

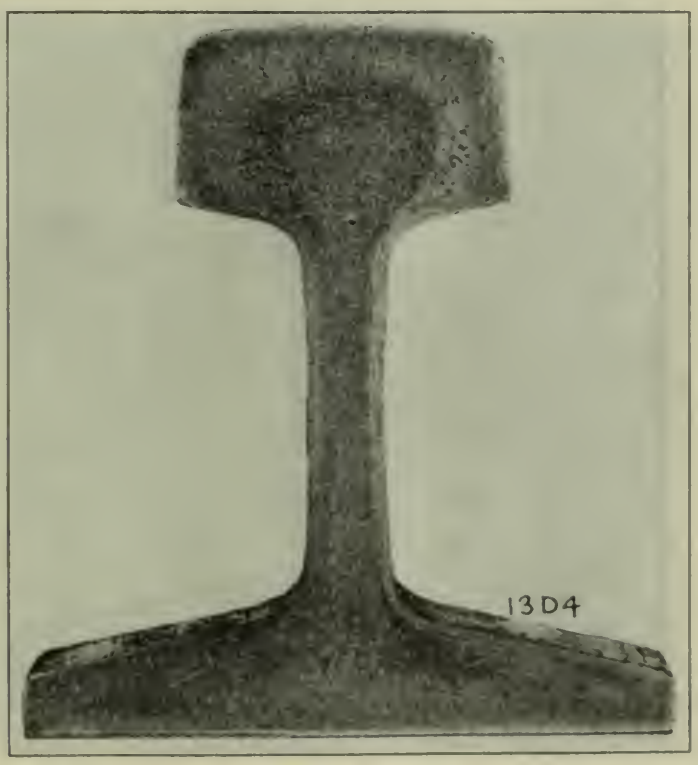


FIG. 74—ETCHED SECTION, 12 FT. FROM TOP END OF D RAIL, 25X30 INGOT.

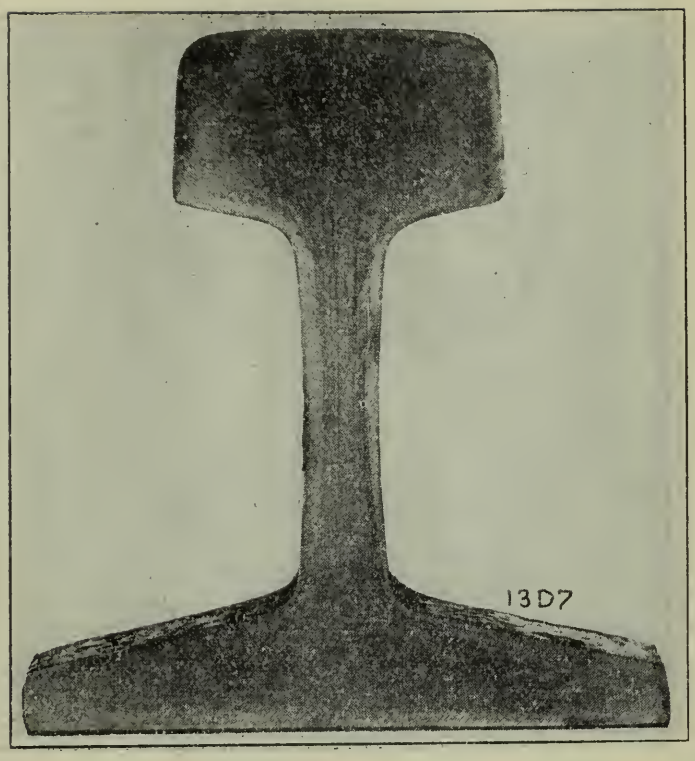


FIG. 75—ETCHED SECTION, 23 FT. FROM TOP END OF D RAIL, 25x30 INGOT.

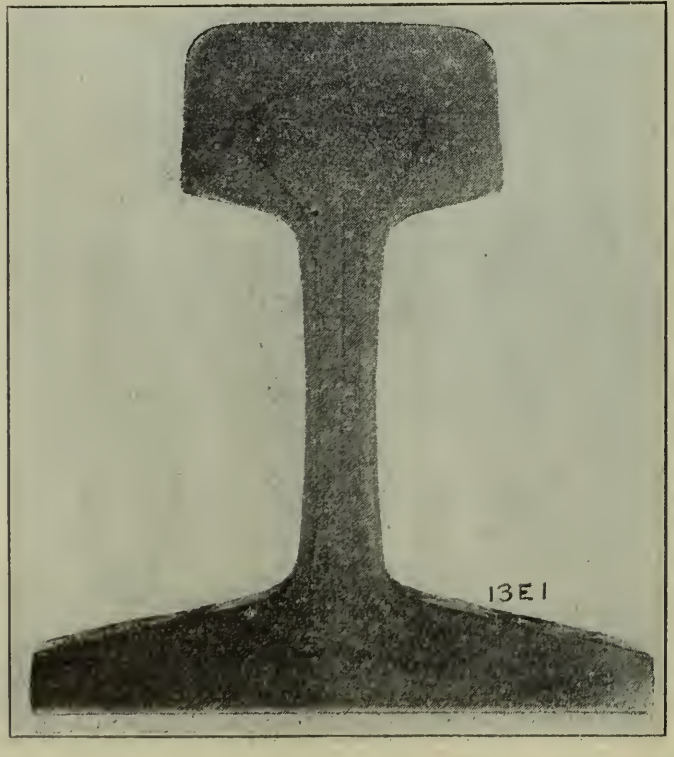


FIG. 76—ETCHED SECTION, 1 FT. FROM TOP END OF E RAIL, 25x30 INGOT.

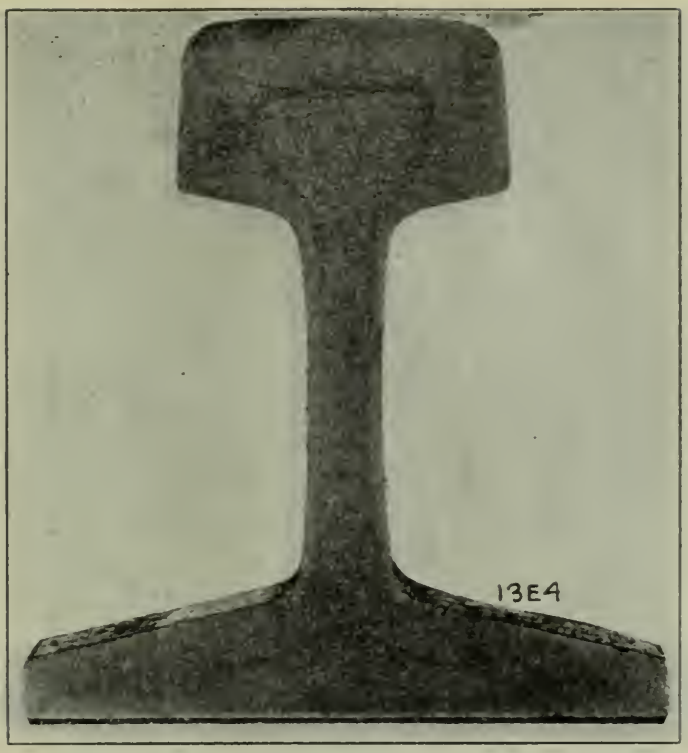


FIG. 77—ETCHED SECTION, 12 FT. FROM TOP END OF E RAIL, 25X30 INGOT.

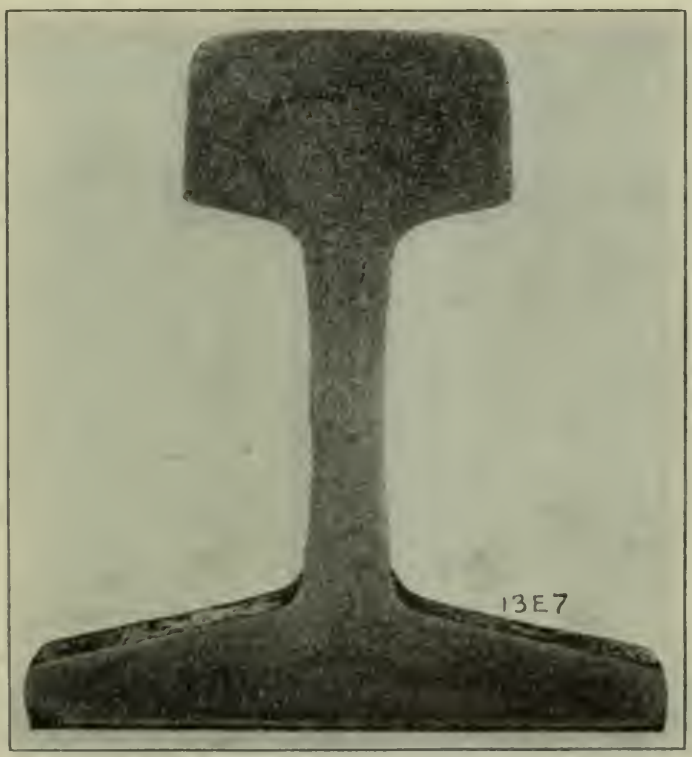


FIG. 78—ETCHED SECTION, 23 FT. FROM TOP END OF E RAIL, 25X30 INGOT.

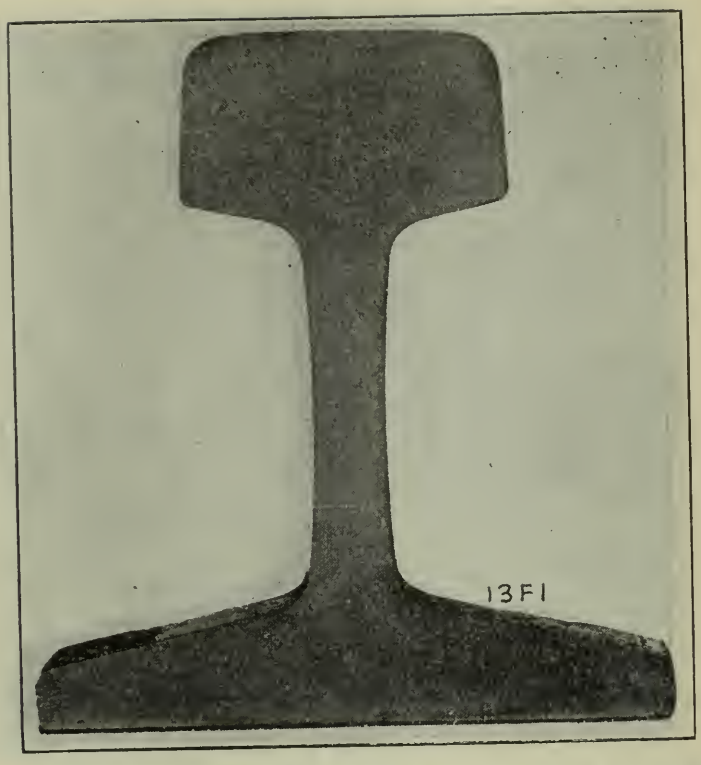


FIG. 79—ETCHED SECTION, 1 FT. FROM TOP END OF F RAIL, 25x30 INGOT.

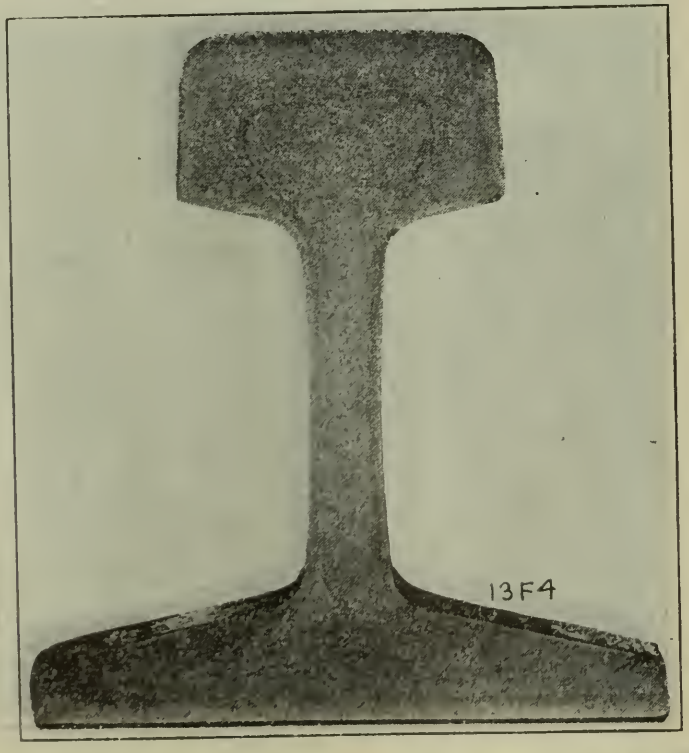


FIG. 80—ETCHED SECTION, 12 FT. FROM TOP END OF F RAIL, 25x30 INGOT.

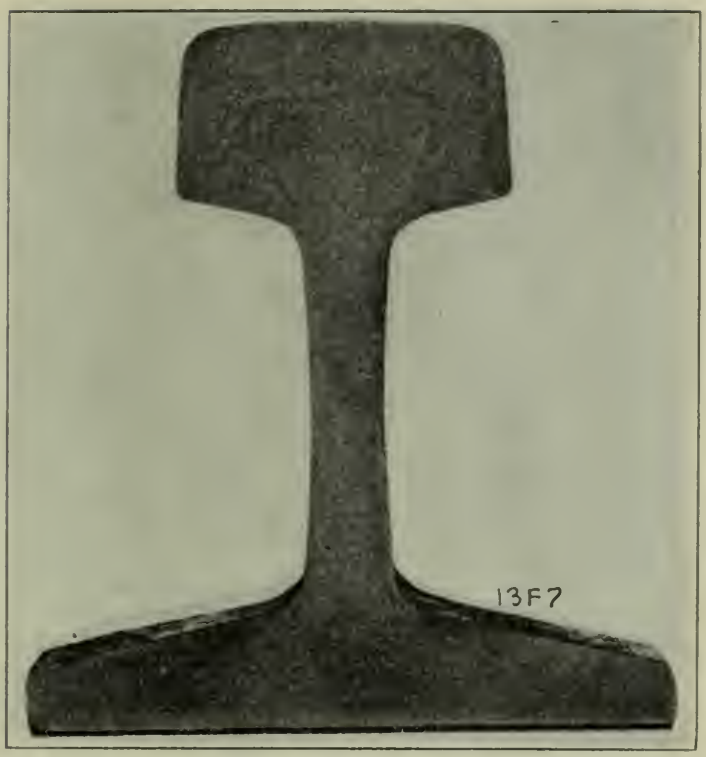


FIG. 81—ETCHED SECTION, 23 FT. FROM TOP END OF F RAIL, 25X30 INGOT.

FIG. 82—ETCHED SECTION, 1 FT. FROM TOP END OF G RAIL, 25X30 INGOT.

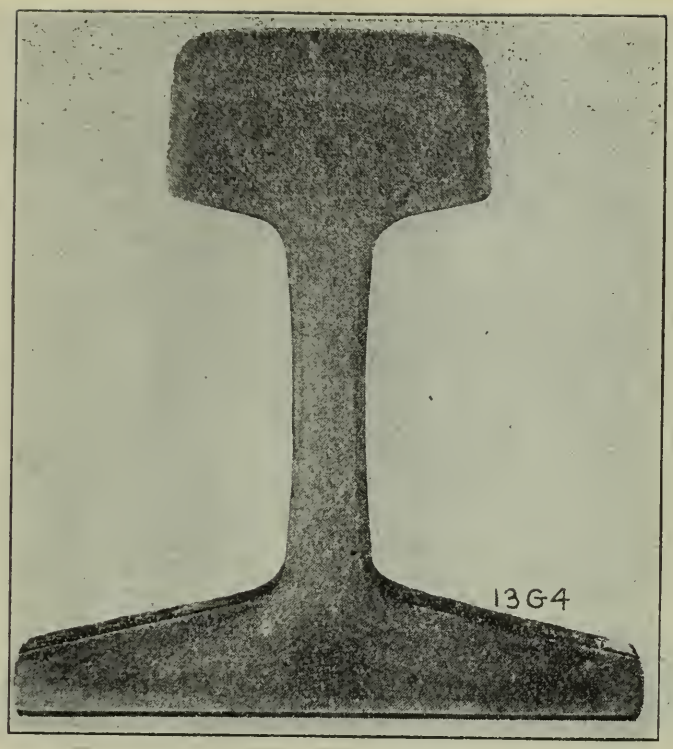


FIG. 83—ETCHED SECTION, 12 FT. FROM TOP END OF G RAIL, 25x30 INGOT.

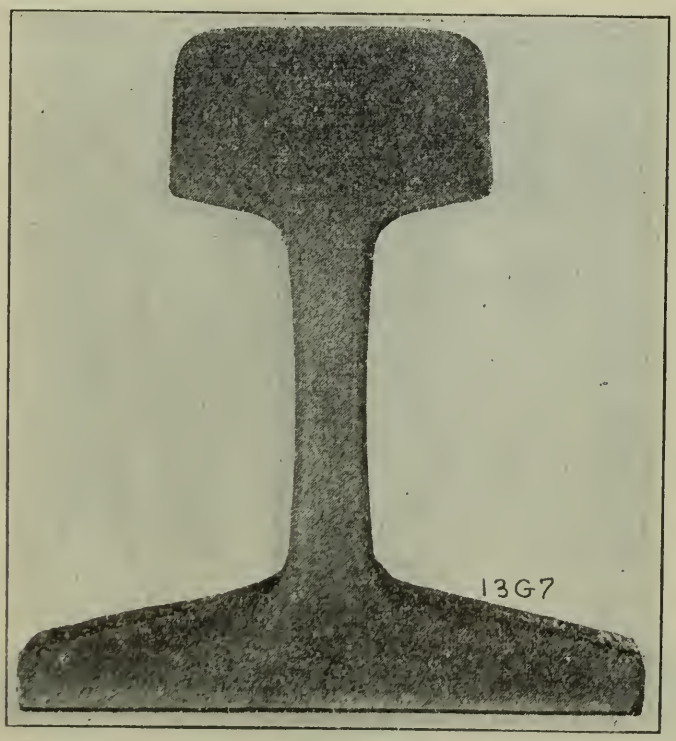


FIG. 84—ETCHED SECTION, 23 FT. FROM TOP END OF G RAIL, 25x30 INGOT.

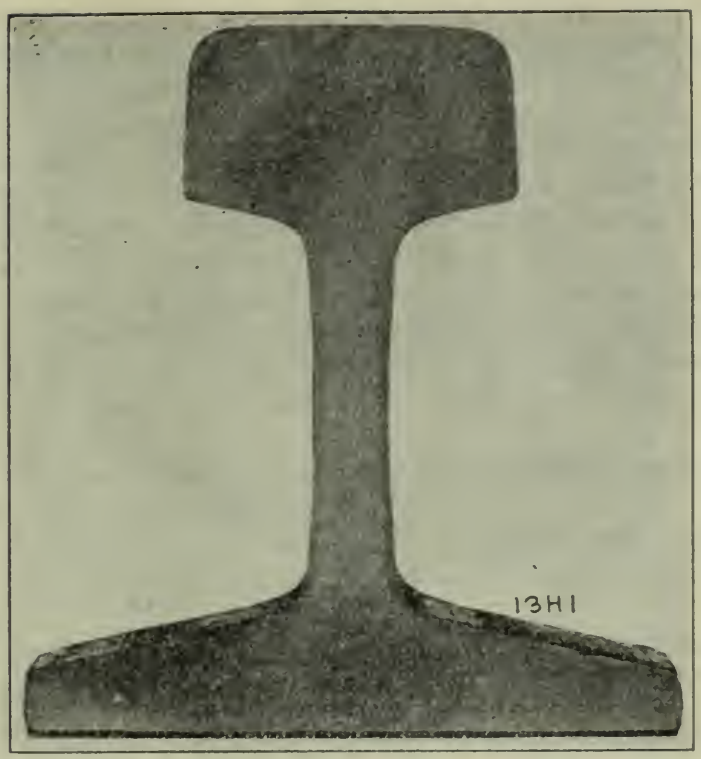


FIG. 85—ETCHED SECTION, 1 FT. FROM TOP END OF H RAIL, 25X30 INGOT.

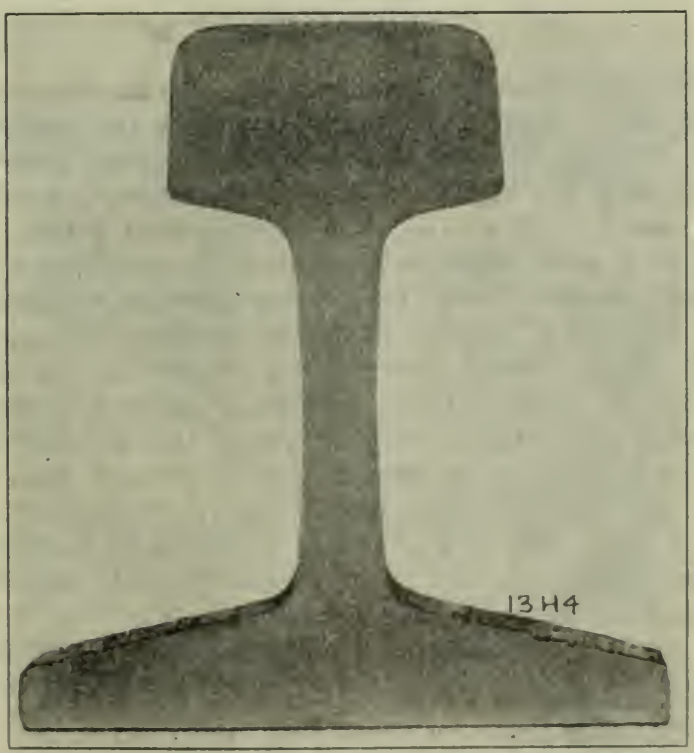


FIG. 86—ETCHED SECTION, 12 FT. FROM TOP END OF H RAIL, 25X30 INGOT.

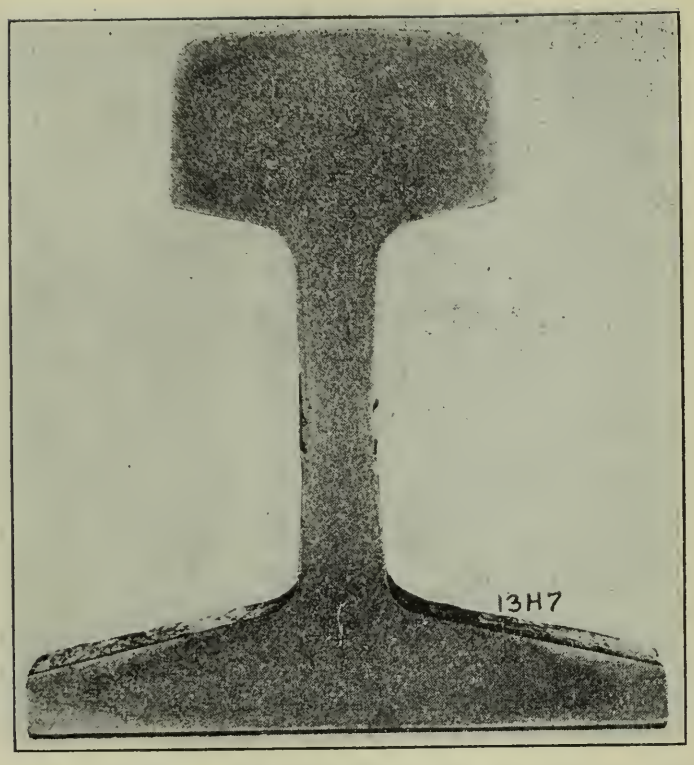


FIG. 87—ETCHED SECTION, 23 FT. FROM TOP END OF H RAIL, 25x30 INGOT.

SUMMARY.

1. This report covers an investigation to throw light on the relationship of the size of ingots of Bessemer rail steel to the segregation of the metalloids, locations of pipes and blow holes, and the properties of the rails. A series of five ingots was made of the following bottom sizes, all 5 ft. high, namely, 12 in. x 12 in., 15 in. x 15 in., 18 in. x 18 in., 20 in. x 24 in. and 25 in. x 30 in. These were split open, after cooling in the molds, one-half used to obtain borings for a chemical survey of the ingot, and the other half for etching. Another similar set of ingots was rolled into rails with only sufficient discard from the top of the bloom to allow rolling into rail, and the entire rail bars from these ingots were used for drop tests, etchings and chemical analyses, except that no rails were rolled from the 12-in. ingot, as an attempt to do so resulted in a "cobble" on account of the small size of the ingot. The 15 x 15 and 18 x 18 ingots were rolled direct into rails according to the usual practice at South Chicago, but the 20 x 24 and 25 x 30 ingots were too large for the rail mill and were first bloomed down to about 14 x 14 or 16 x 16 in. in a two high mill, cut in two, brought back and placed into the rail mill soaking pits and then rolled into rails. In this there was a considerable divergence from the usual practice.

The statements and conclusion in this summary refer to Bessemer steel, made under the conditions prevailing in these tests, the object of

which was stated in the previous paragraph, and proper care must be used when applying them to other material and other conditions. The rail section tested was the 100-pound A. R. A. type B section.

Especial attention is called to the fact that the investigation of the ingots was necessarily made after they had been allowed to become cold; a condition which does not obtain in regular rail mill practice, and one which it is often claimed exaggerates the size of the pipe as compared with ingots which are not allowed to cool.

2. With ingots five feet high and varying in cross-section from 12x12 inches to 25x30 inches, the "pipe" or shrinkage cavity extends downward a decreasing distance as the diameter of the ingot increases. The variation is from about 80 per cent. in the small ingot to about 35 per cent. in the largest ingot.

3. The condition of "sponginess" extends downward about 30 per cent. from the top in all the ingots.

4. The blowholes around the axes of the ingots were slag-coated, while those close to the walls seemed to have a clean metallic surface free from slag.

5. The chemical survey of the ingots shows a concentration or segregation of carbon, phosphorus and sulphur, and to a much smaller extent also of manganese, in the upper part of the ingot around the axis. The concentration increases in general as the size of the ingot increases. The increases above the average content of the steel vary from 32 per cent. in the 12x12 ingot to 119 per cent. in the 25x30 ingot in carbon, from 102 per cent. to 225 per cent. in phosphorus, and from 100 per cent. to 369 per cent. in sulphur.

6. The top of the ingot along the axis shows a decrease in the above elements, and the axis also shows some decrease in the lower part of the ingot. The region figured as a percentage of the total volume of the ingot covered by this metal of lower content of metalloids increases in general as the size of the ingot increases.

7. In the upper part of the ingot the outside portion or walls of the ingot show negative segregation or decrease of carbon, phosphorus and sulphur. The negative segregation is greatest at the top and gradually becomes less until the average composition of the steel is reached, when the walls remain of about the average composition for the rest of the distance to the bottom of the ingot. The greatest decrease is, roughly, about 25 per cent. in carbon for all the ingots. The greatest decrease in phosphorus ranged from 32 to 45 per cent., and in sulphur from 43 to 63 per cent., showing a tendency to increase as the size of the ingot increases. The distance that the negative segregation in the wall extends downward from the top of the ingot increases as the size of the ingot increases, ranging from about 30 per cent. to about 50 per cent.

8. Drop tests were made of the complete rail bars from 15x15, 18x18, 20x24 and 25x30-inch ingots. The ductility of the material was determined by putting gage marks one inch apart over a space of six inches on the part in tension, and the per cent. of stretch in the inch which

stretched most at failure in the drop machine, is taken as the measure of ductility. Both with the head in tension and with the base in tension, the rail bar at first decreases in ductility as we go down the ingot, until the minimum ductility is reached at about 20 per cent. by weight from the top of the ingot for all sizes of ingots. Then the ductility again increases until the middle of the ingot is reached, when the ductility remains about constant for the rest of the bar. With the head in tension the minimum ductility is about 6 per cent. elongation, and with the base in tension about 12 per cent. In the lower half of the ingot the rail shows more ductility with the head in tension than with the base, averaging about 23 per cent. elongation with the head in tension, and about 19 per cent. with the base in tension. These are average results, applying to all sizes of ingots.

9. The deflection or permanent set in the drop test was measured after the first blow from a height of 20 ft. of a tup of 2,000 lbs. and with a span of supports of 3 ft. The deflection is greatest at the top end of the rail bar and gradually becomes less as we go down the ingot, until a minimum deflection is reached at distance varying from about 20 per cent. to 40 per cent. from the top. That is, the rail bar is stiffest at about this distance from the top. The zone of maximum stiffness moves downward as the size of the ingot increases, 20 per cent. applying to the 15x15 ingot and 40 per cent. to the 25x30 ingot. The minimum deflection is, roughly, the same for all the ingots, but the maximum seems to increase in general with the size of the ingot. Passing the zone of maximum stiffness, the deflection again increases, but does not become as great as in the extreme top end. The deflection with the head in tension is slightly greater than with the base in tension.

10. The zone of minimum ductility corresponds roughly with the region of greatest interior segregation, and the zone of maximum stiffness corresponds roughly with the region where negative segregation in the walls of the upper part of the ingot ceases.

11. In the zone of minimum ductility all the rail bars failed under one blow of the tup with the head in tension, while in the more ductile regions the rail may stand four or five blows with the head in tension. With the base in tension in the ductile regions the rail may stand four or five blows with all the rail bars. In the zone of least ductility and with the base in tension the number of blows necessary to break the rail becomes less as the size of the ingot increases, the number of blows varying from two to three or four.

12. Analyses of samples from the finished rail bar indicate that the distribution of the elements is about the same as in the ingot.

13. The carbon, phosphorus, sulphur and manganese in general segregate together; that is, they collect into the same regions, although the percentages of concentration differ.

14. The samples from the upper corner of the head and from the edge of the flange show practically the same composition in almost all cases.

15. Etchings of sections of rail from the upper part of the ingot show streaks and spots which correspond to the region of sponginess in the upper part of the ingot. Etchings of rail sections from the upper part of the ingot may also show a "dark core" corresponding to the region of strong segregation found in the ingot, and from the lower part of the ingot may show a "light core" corresponding to the region of negative segregation.

16. In conclusion, I wish to again acknowledge the prompt and efficient work done by the Metallurgical, Chemical and other departments of the South Works of the Illinois Steel Company in carrying out this investigation.

Appendix D.

*TESTS OF RAIL STEEL INGOTS AND DERIVATIVE SHAPES MADE AT WATERTOWN ARSENAL.

DIGEST AND ANALYSIS.

By

M. H. Wickhorst, Engineer of Tests, Rail Committee.

This report is intended primarily as a digest and analysis of the investigation of rail steel ingots and derivative shapes made at Watertown Arsenal, Mass., under the direction of James E. Howard, and shown in "Tests of Metals, etc." for 1909. Its main purpose is to determine, if possible, what conclusions may be drawn from the results of the tests.

The general method of the work is explained on page 5 of "Tests of Metals," as quoted below: (Unless otherwise stated, page numbers hereafter refer to "Tests of Metals," 1909.) "Beginning with the ingot, the structural state of the metal was examined by taking cross sections and longitudinal sections. This method was carried through the various successive derivative shapes, and the results obtained are shown in the large number of illustrations which form the body of the report. The illustrations are so arranged as to show the progressive changes in the character of the metal from its initial state in the ingot to its final condition in the finished product. Tensile test bars were taken at successive stages of the rolling, from the blooming passes to the rail mill."

The greater part of the work was devoted to Bessemer rail steel, five acid Bessemer heats being made for this series of tests, each heat furnishing six ingots about 19½x20½ in. at the bottom and about 5 ft. high. The schedule of tests and operations is shown on page 14 and is herewith given as table 1:

CAVITIES IN INGOTS AND SHAPES.

The Report contains a great many interesting and very well executed illustrations of longitudinal and transverse sections of ingots and shapes, both plain and etched, and they throw considerable light on the matter of cavities, blow holes and general sponginess in the ingot and succeeding rolled shapes. A number of the longitudinal sections of ingots and blooms are reproduced herewith as Figs. 1 to 9, inclusive. Fig. 1 shows

*Report No. 20, September, 1911.

TABLE I—SCHEDULE OF BESSEMER INGOTS AND THEIR TREATMENT.

HEAT NO. 1.

Distinguishing marks.	Treatment of ingot.	Time in furnace. Hours.	Minutes.	Remarks.
1A	Cooled in vertical position without soaking.	.....	.....	
1B	Soaked and then cooled in vertical position.	1	30	
1C	Charged hot and soaked as usual...	1	30	Rolled into blooms and then cut in center at shears.
1D	.....do.....	1	30	Rolled into 75-pound section rails.
1E	Laid on side to cool immediately after stripping, head side up; reheated.	6	00	Rolled into blooms, then cut in center at shears.
1F	.....do.....	6	00	Rolled into 75-pound section rails.

HEAT NO. 2.

2A	Cooled in vertical position without soaking.	.....	.....	
2B	Soaked and then cooled in vertical position.	1	30	
2C	Charged hot and soaked as usual...	1	30	Rolled into blooms and then cut in center at shears.
2D	.....do.....	1	30	Rolled into 75-pound section rails.
2E	Laid on side to cool immediately after stripping, head side up; reheated.	9	00	Rolled into blooms, then cut in center at shears.
2F	.....do.....	9	00	Rolled into 75-pound section rails.

HEAT NO. 3.

3A	Cooled in vertical position without soaking.	.....	.....	
3B	Soaked and then cooled in vertical position.	1	30	
3C	Charged hot and soaked as usual...	1	30	Rolled into blooms and then cut in center at shears.
3D	.....do.....	1	30	Rolled into 75-pound section rails.
3E	Laid on side to cool immediately after stripping, web side up; reheated.	9	00	Rolled into blooms, then cut in center at shears.
3F	.....do.....	9	00	Rolled into 75-pound section rails.

HEAT NO. 4.

4A	Charged hot and soaked as usual...	1	30	Rolled through third roughing pass.
4B	.....do.....	1	40	Rolled through fifth roughing pass.
4C	.....do.....	1	50	Rolled through squabbing pass.
4D	.....do.....	2	00	Rolled through first forming pass.
4E	.....do.....	2	10	Rolled through second forming pass.
4F	.....do.....	2	20	Rolled through finishing pass.

HEAT NO. 5.

5A	Charged hot and soaked as usual...	1	30	Rolled 3 passes in bloom mill.
5B	.....do.....	1	30	Rolled 6 passes in bloom mill.
5C	.....do.....	1	30	Rolled 9 passes in bloom mill.
5D	Cooled in vertical position; reheated.	8	00	Rolled 3 passes in bloom mill.
5E	.....do.....	8	00	Rolled 6 passes in bloom mill.
5F	.....do.....	8	00	Rolled 9 passes in bloom mill.

a longitudinal section one inch from the axis of an ingot that was cooled in a vertical position without soaking, and Fig. 2 shows an axial longitudinal section of a similar ingot which was first soaked for 1½ hours and then cooled in a vertical position. For the purpose of comparing the interior cavities in the two treatments of the ingot, the comparison is best made with axial longitudinal sections, but unfortunately such a section is not shown for the first ingot, and Fig. 3 is given, showing a longitudinal section one inch from the axis of the second ingot. A study of these three figures shows that the central "sponginess" or "honeycomb" extends downward to about the middle in both ingots, although most of it is confined to the upper third. The difference between the two is not great, but the central sponginess seems to have been aggravated, if anything, by the soaking given the second ingot before final cooling. The sponginess in the walls of the direct-cooled ingot extend downward about 25 per cent. from the top, and in the soaked ingot it extends downward a somewhat greater distance, or about 30 per cent. It should also be stated that the direct-cooled ingot showed a large transverse crack about the middle, covering almost the entire cross section of the ingot.

Next are given three illustrations of longitudinal axial sections of blooms at different stages of reduction from ingots which were charged hot and rolled after soaking 1½ hours. Fig. 4 shows an axial section of a bloom after the third pass, reduced to 18.3x18.6 in. from about 19½x20½ in. The central sponginess extends down to about the middle of the bloom with most of it contained in the upper third and the peripheral sponginess extends downward about 25 or 30 per cent. Fig. 5 shows a section of a similar ingot after six passes, bloomed to 12.5x19.3 in., and Fig. 6 shows one after nine passes bloomed to 11.7x12.7 in. or a reduction to about one-third of the original cross-sectional area. Here again the central sponginess extends down to about the middle of the bloom with most of it in the upper third of the bloom, and the cavities are seen to have been not closed up by a two-thirds reduction. The small peripheral holes seem to have been largely closed up after the sixth pass or about one-half reduction, and after the ninth pass do not show in the photograph of the planed surface. The reproductions of etched sections, however, given in the Report, show them distinctly.

The next three illustrations, Figs. 7, 8 and 9, show axial longitudinal sections of blooms at different stages of reduction, of ingots that had been allowed to cool in a vertical position and then put in the furnace for eight hours. Fig. 7 shows a bloom after the third pass, Fig. 8 shows one after the sixth pass, and Fig. 9 shows one after the ninth pass. The same remarks apply to these blooms that have been made regarding the previous ones, except that the cavities in the upper third of the bloom compose a somewhat smaller part of the volume of the material than in the blooms made from ingots which were at once placed in the soaking pit. This corresponds to what was found on examination of the ingots before any work of rolling was done on them.

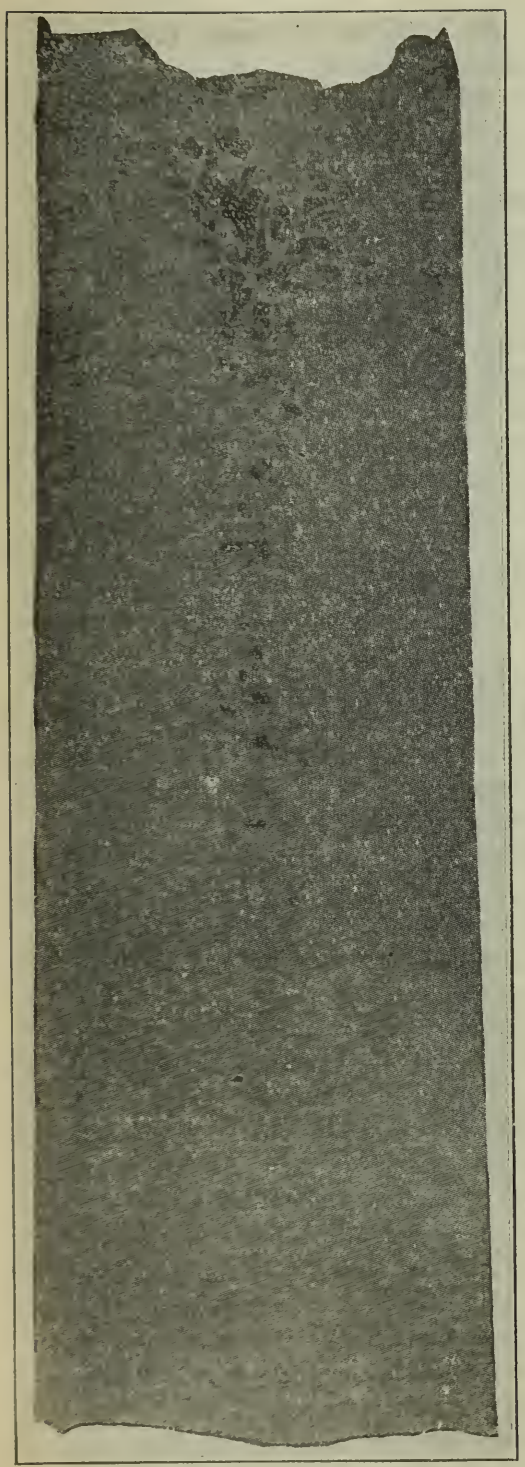


FIG. 1—INGOT 1 A, COOLED IN VERTICAL POSITION WITHOUT SOAKING. LONGITUDINAL SECTION 1 IN. FROM AXIS.

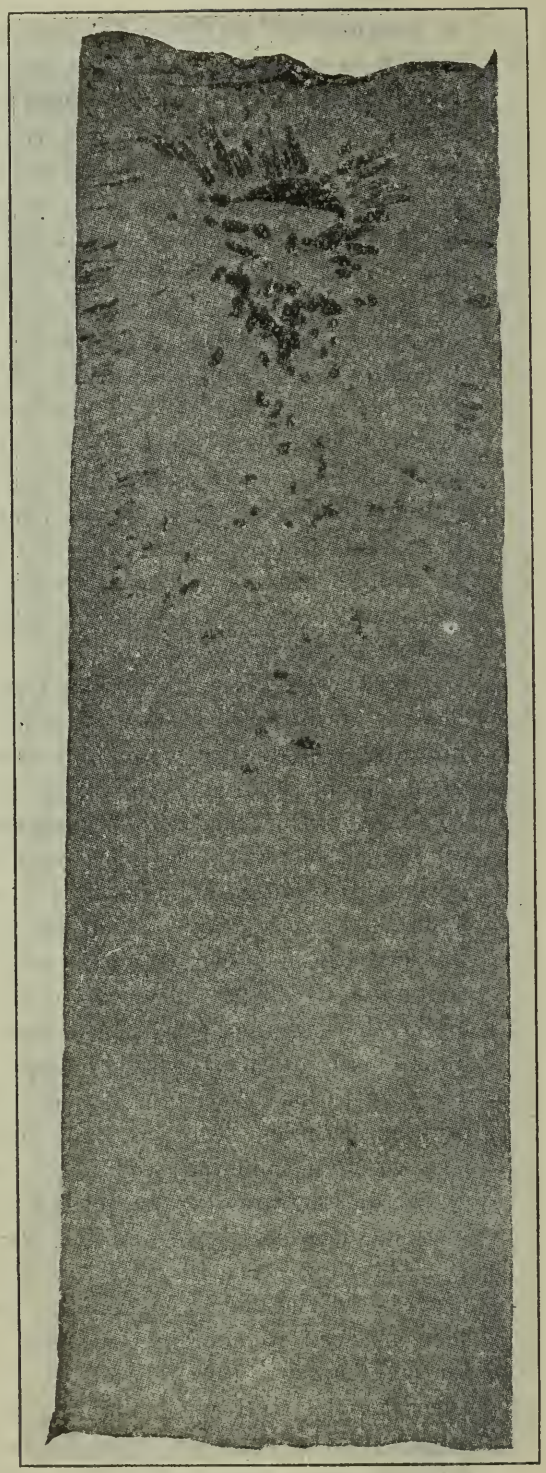


FIG. 3—INGOT 1 B, SOAKED AND COOLED IN VERTICAL POSITION. LONGITUDINAL SECTION 1 IN. FROM AXIS.

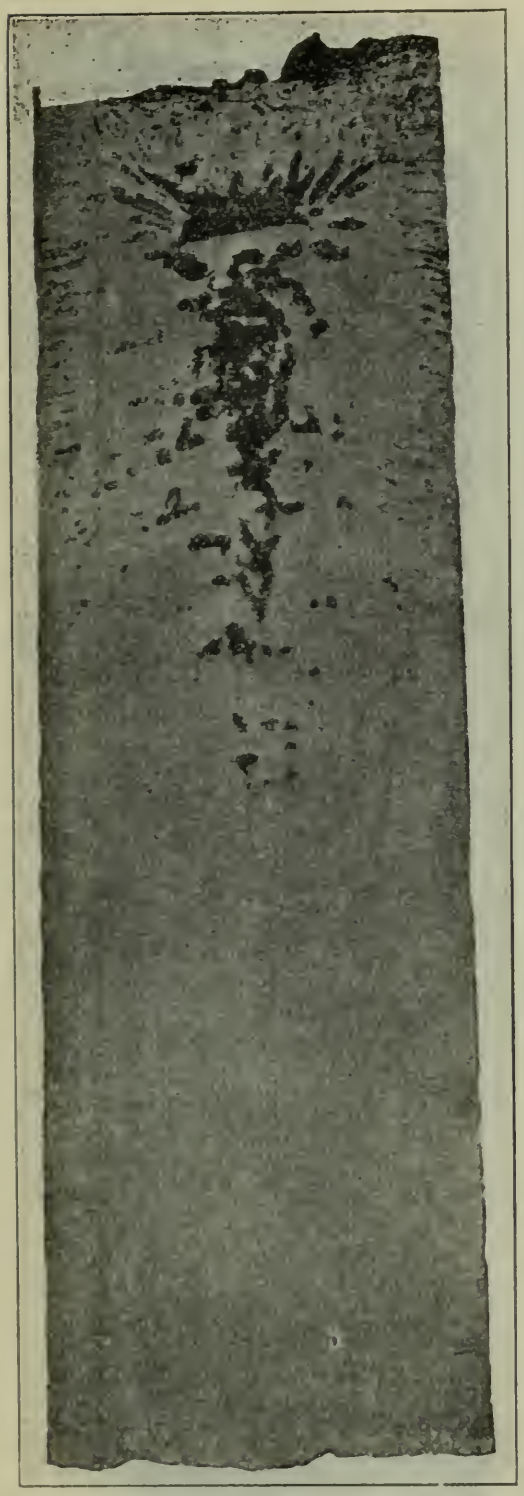


FIG. 2—INGOT 1 B, SOAKED AND COOLED IN VERTICAL POSITION. AXIAL LONGITUDINAL SECTION.

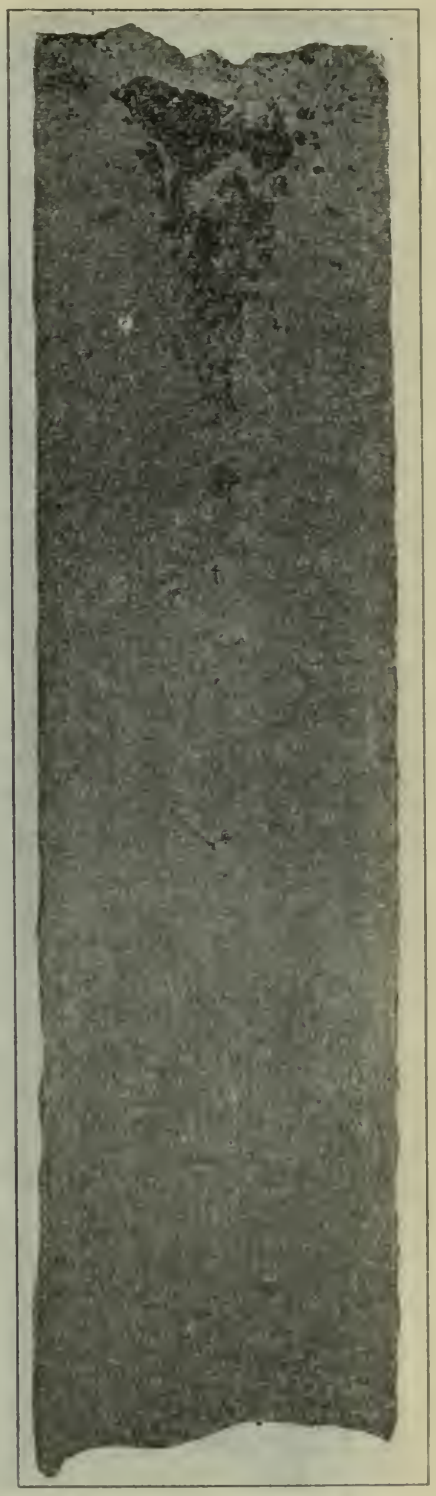


FIG. 4—BLOOM AFTER 3RD PASS 18.3 x 18.6 IN. FROM INGOT 5 A, CHARGED HOT AND SOAKED AS USUAL. AXIAL LONGITUDINAL SECTION.

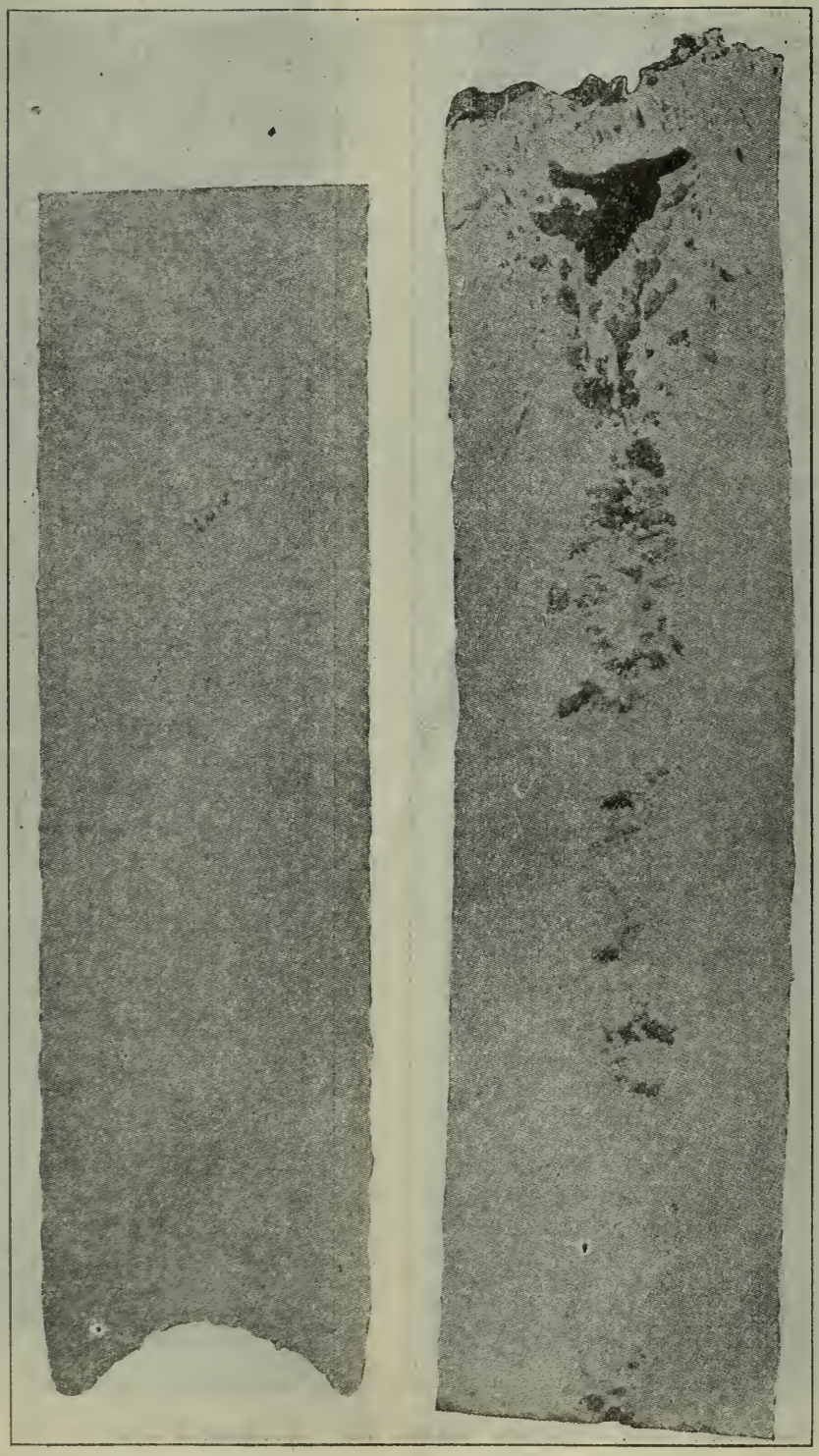


FIG. 5—BLOOM AFTER 6TH PASS 12.5 x 19.3 IN. FROM INGOT 5 B. CHARGED HOT AND SOAKED AS USUAL. AXIAL LONGITUDINAL SECTION OF SMALL DIAMETER.

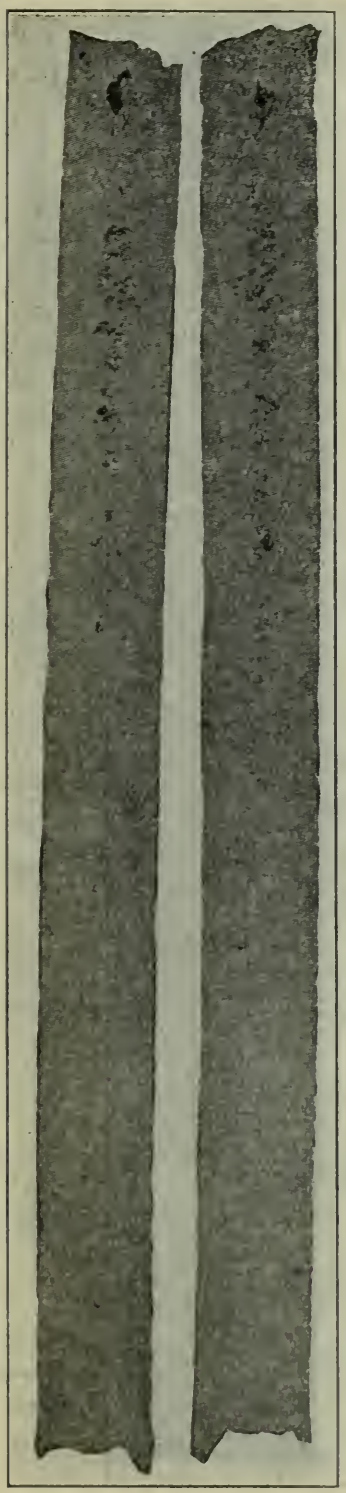


FIG. 6—BLOOM AFTER 9TH PASS, 11.7 x 12.7 IN. FROM INGOT 5 C. CHARGED HOT AND SOAKED AS USUAL. ONE SURFACE ON AXIAL PLANE AND OTHER 1 IN. FROM AXIS.

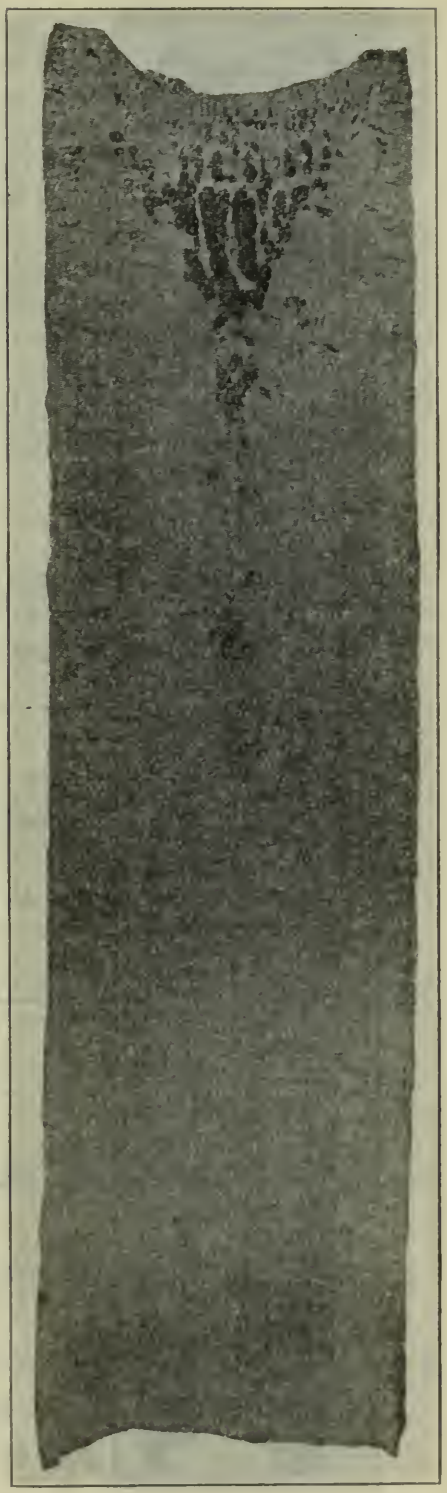


FIG. 7—BLOOM AFTER 3RD PASS, 18.3 IN. SQ. FROM INGOT 5 D, COOLED IN VERTICAL POSITION AND THEN PUT IN FURNACE FOR 8 HRS. AXIAL LONGITUDINAL SECTION.

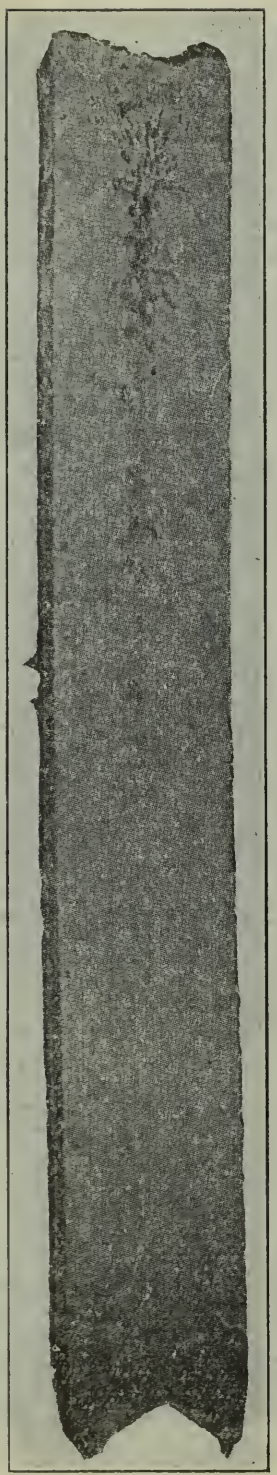


FIG. 8—BLOOM AFTER 6TH PASS, 12.4 x 19.4 IN. FROM INGOT 5 E, COOLED IN VERTICAL POSITION AND THEN PUT IN FURNACE FOR 8 HRS. AXIAL LONGITUDINAL SECTION.

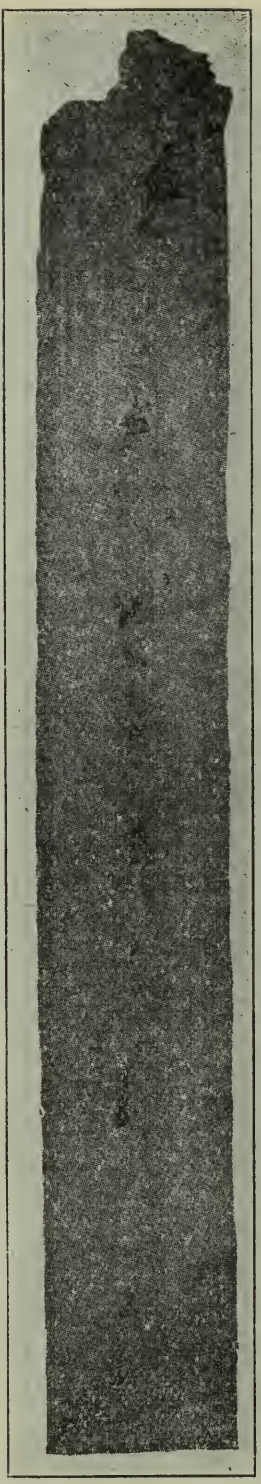


FIG. 9—BLOOM AFTER 9TH PASS, 11.3 x 12.7 IN. FROM INGOT 5 F, COOLED IN VERTICAL POSITION AND THEN PUT IN FURNACE FOR 8 HRS. AXIAL LONGITUDINAL SECTION OF UPPER HALF OF BLOOM.

The above discussion concerning ingots and blooms indicates: *First, that the upper third of the ingot is very spongy; second, that the cavities compose a little larger part of the volume of the material, both of the ingot and of the bloom, where the ingot is soaked without first cooling down; third, that the cavities are distributed in the bloom about as they were in the ingot from which it was rolled.*

Beyond the bloom the interior of the shapes is represented mostly by etched cross sections and they show that the larger cavities persist well toward the finished rail. The smaller cavities seem not to show directly in the plain surfaces of the much-reduced sections, but the etched sections show spots and streaks corresponding to the cavities in the ingot and bloom, although the spots and streaks seem to be more numerous than the cavities shown by the cross sections of the ingot and bloom.

CARBON IN BLOOMS.

Carbon determinations by color are shown in the Report, on two axial longitudinal sections of blooms, one after the sixth blooming pass and the other after the ninth blooming pass, the ingots having been charged hot

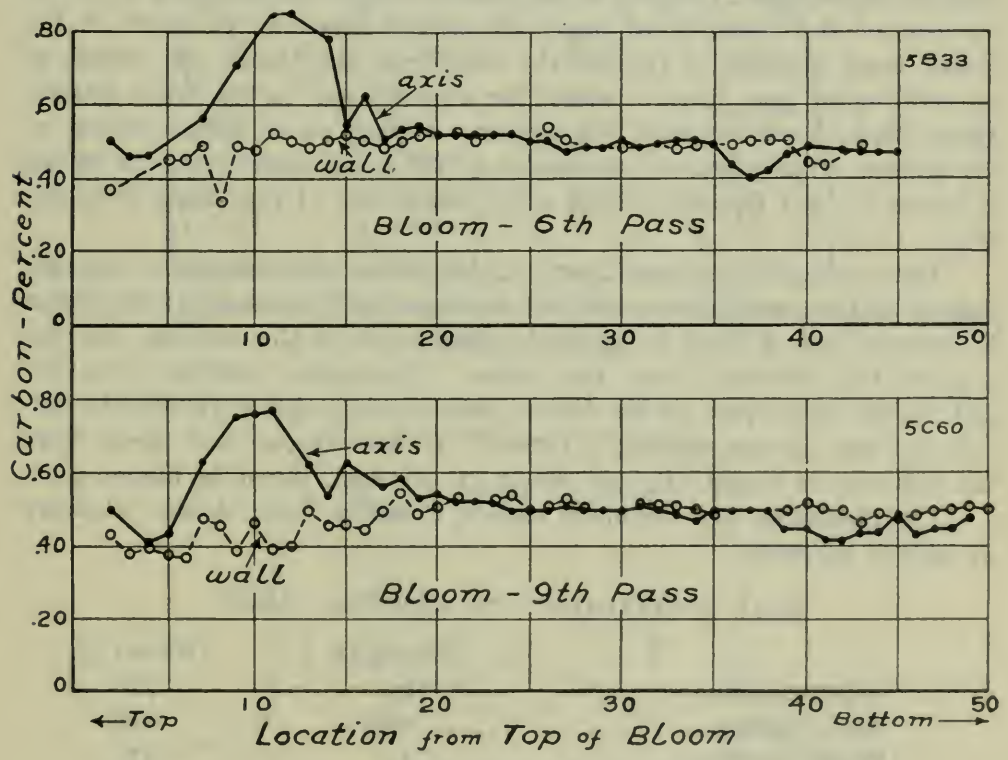


FIG. 10—CARBON IN BLOOMS.

and soaked as usual. From each bloom samples were taken from twelve longitudinal rows of holes. The holes in each row were spaced apart about two per cent. of the length of the bloom and were numbered, beginning with one at the top end of the bloom. At any given distance

from the top end of the bloom, the extreme differences of carbon in the cross section are generally shown by the samples at the axis and in the walls of the bloom, as shown by a study of the results, following page 93 for the bloom from ingot 5B after the sixth blooming pass, and following page 99 for the bloom from ingot 5C after the ninth blooming pass. In order to show the variations of composition throughout the bloom, I have plotted the carbon for two of the rows of samples of each bloom, row G representing the axis of the bloom and row L representing the wall, as shown in Fig. 10 herewith. The per cent. of carbon is plotted vertically, and the number of the hole from the top end of the bloom is plotted horizontally. Other work has indicated that the samples from the wall of an ingot below the middle represent fairly closely the average steel of the ingot, and assuming this to hold with the present blooms, the average carbon in these blooms was about .50 per cent.

At the top end of the bloom the axis shows carbon below the average or negative segregation, reaching a minimum at about 6 or 8 per cent. from the top, but the carbon soon increases and shows considerable positive segregation, reaching a maximum at about 24 per cent. from the top end of the bloom from ingot 5B, and at about 22 per cent. in the bloom from ingot 5C. Toward the middle of the bloom, the carbon at the axis again gets down to about the average, and in the lower quarter again shows some negative segregation, coming up to about normal at the bottom. The negative segregation in the lower quarter is well shown in bloom 5C, but through only a small percentage of the length in bloom 5B.

The walls of the upper part of the bloom show negative segregation of carbon, which rises until the average carbon content of the bloom is reached and it then in general remains about the average for the rest of the distance down the bloom. Successive samples from the wall in the upper part of the bloom show considerable variations in carbon, but the average content is reached at about 25 per cent. down from the top end in bloom 5B, and about 35 per cent. down in bloom 5C.

The maximum and minimum carbon found in these blooms is shown in table 2 herewith.

TABLE 2—MAXIMUM AND MINIMUM CARBON.

	Bloom 5B.	Bloom 5C.
Axis, maximum	.85	.77
Axis, increase	70%	54%
Walls, minimum	.34	.37
Walls, decrease	32%	26%

TENSILE TESTS.

Tensile tests were made of specimens taken at various stages from the ingot to the finished rail, and the results are interesting as having

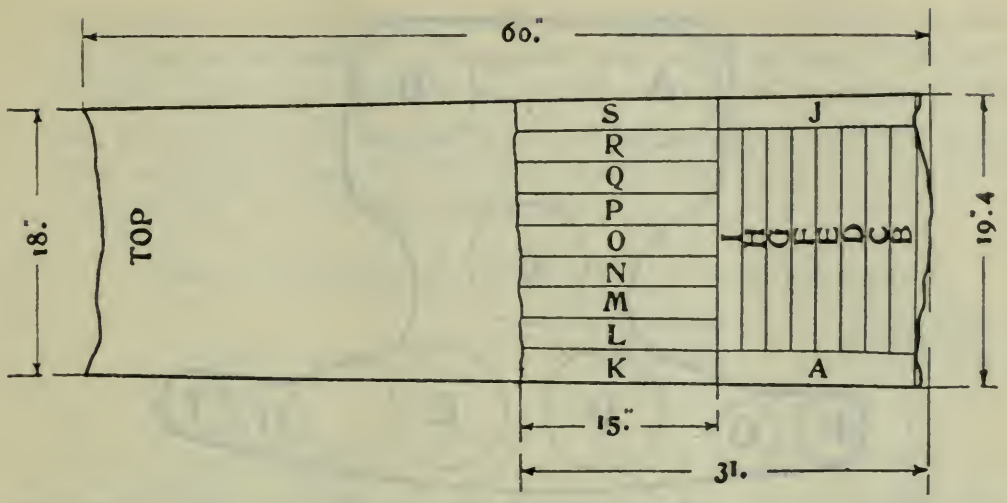


FIG. 11—LOCATIONS OF TENSILE SPECIMENS FROM LONGITUDINAL SLICE OF INGOT 1A PASSING THROUGH AXIS.

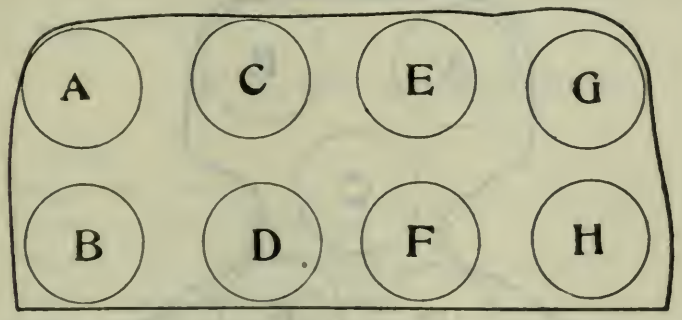


FIG. 12—LOCATIONS OF LONGITUDINAL TENSILE SPECIMENS FROM UPPER SIDE OF BLOOM, 1E.

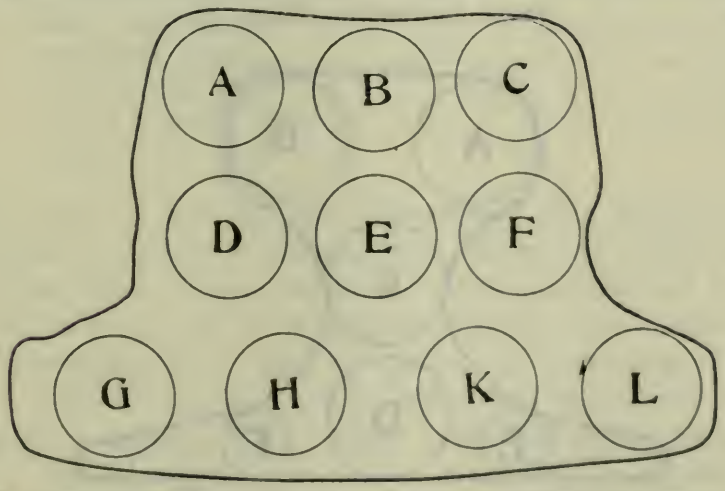


FIG. 13—LOCATIONS OF LONGITUDINAL TENSILE SPECIMENS FROM SECTION AFTER THIRD ROUGHING PASS, 4A.

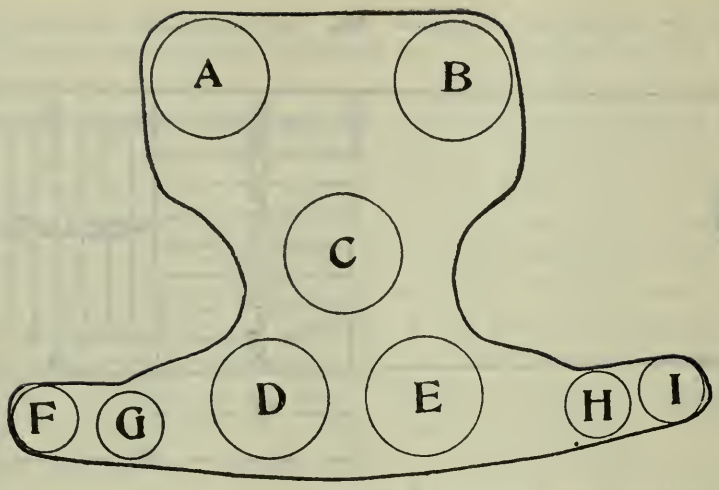


FIG. 14—LOCATIONS OF LONGITUDINAL TENSILE SPECIMENS FROM SECTION AFTER FIFTH ROUGHING PASS, 4B.

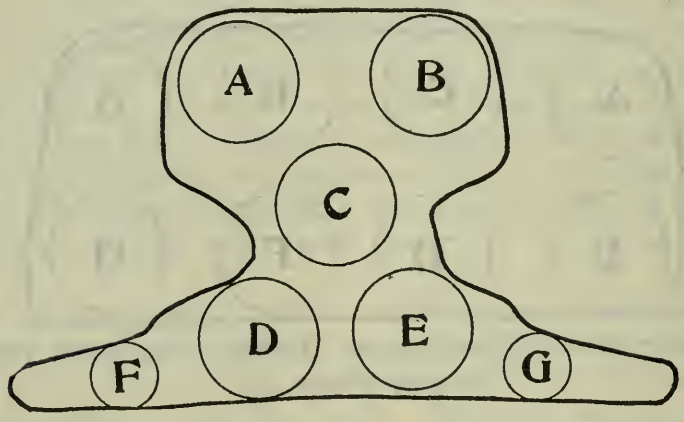


FIG. 15—LOCATIONS OF LONGITUDINAL TENSILE SPECIMENS FROM SECTION AFTER SQUABBING PASS, 4C.

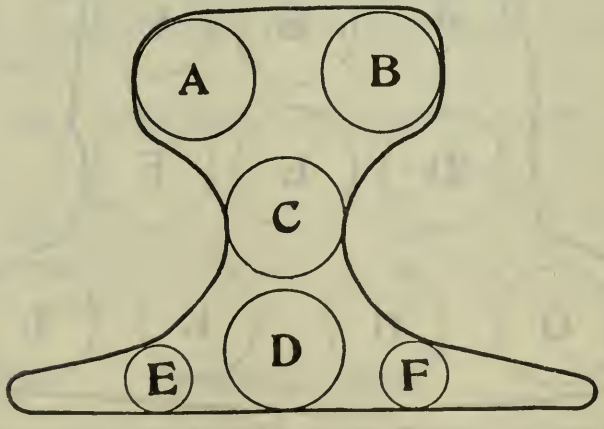


FIG. 16—LOCATIONS OF TENSILE SPECIMENS FROM SECTION AFTER FIRST FORMING PASS, 4D.

a bearing on the question of the amount of work or reduction necessary in rolling to develop the full physical qualities of the steel. In table 3 I give a list of the illustrations which are herewith reproduced, showing how the tensile test specimens were taken from the different shapes. The specimens as tested were .798 diameter, which equals a sectional area of .50 sq. in., and the gage length was 10 in.

TABLE 3—ILLUSTRATIONS OF LOCATIONS OF TENSILE SPECIMENS.

Pass.	Fig. Number of this Report.	From page of Tests of Metals.
Ingot	11	65
Bloom	12	111
Third roughing	13	169
Fifth roughing	14	241
Squabbing	15	291
First forming	16	335

The areas of the various passes represented by tensile tests are shown in table 4.

TABLE 4—AREAS AT VARIOUS PASSES.

Pass.	Area, sq. in.
Ingot, top, 18x19	342
Ingot, 5 per cent. from top	345
Ingot, 25 per cent. from top	357
Ingot, 50 per cent. from top	371
Ingot, 90 per cent. from top	393
Ingot, bottom, 19.5x20.5	400
Bloom, 7.65 in. x 7.8 in.	59.7
Third roughing pass	32.2
Fifth roughing pass	24.3
Squabbing pass	17.8
First forming pass	14.1
Second forming pass	10.8
Finished rail, 75 lb.	7.4

In order to show up more conveniently than shown by the tables, the relation between the distance from the top end of the shape and the tensile properties, I have plotted the tensile strength and elongation for the various passes, of metal representing the axis of the section, and also the exterior of the section, showing the distance from the top end of the shape in per cent., horizontally, and the tensile strength and elongation vertically. The various tables of tensile results given in Tests of Metals, which I have drawn from for these diagrams, are shown in table 5 herewith.

TABLE 5—TENSILE TESTS.

Pass.	Fig. Number of this Report.	From page of Tests of Metals.
Ingot	17	82
Bloom	18	152
Third roughing pass	19	232
Fifth roughing pass	20	282
Squabbing pass	21	327
First forming pass	22	368
Second forming pass	23	416
Rail	24	583

These various tests are all from heat No. 4, except those on the ingot, which was ingot A of heat 1, and those on the bloom, which were made from ingot 1E. The interior metal is represented in the diagrams in the shapes from the third roughing to the first forming pass, inclusive.

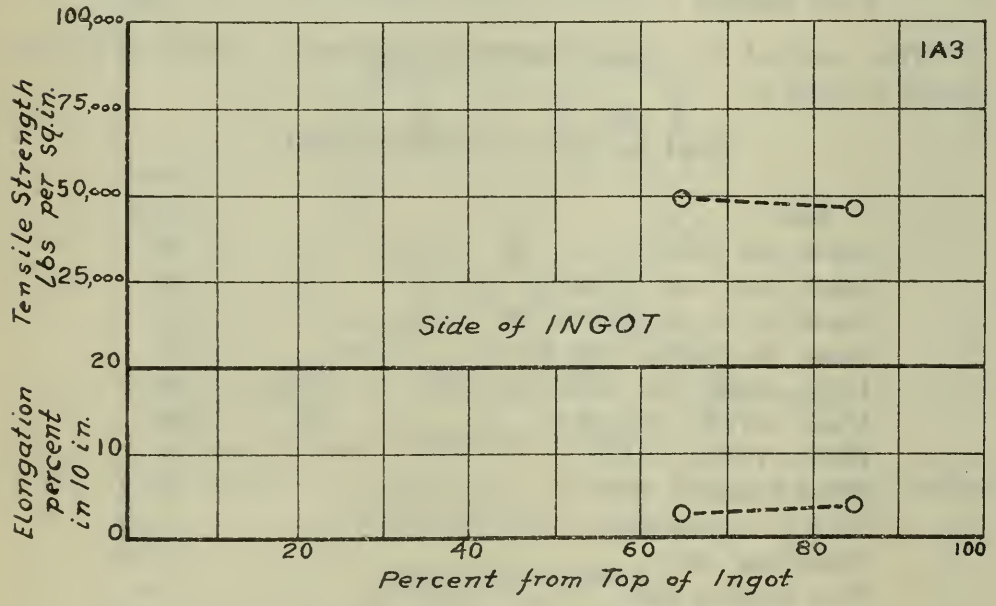


FIG. 17—TENSILE TESTS FROM SIDE OF INGOT.

and the results used for plotting are of the test pieces taken from the center of the section or the web. The test pieces were almost .8 in. in diameter, and in the shapes of large sectional area represent fairly well only the axial metal, but in the smaller shapes considerable of the exterior metal is also included. The exterior metal, or what was the wall of the ingot, is represented in the diagrams in the shapes from the ingot to the first forming pass, inclusive. In the ingot the samples were taken from the middle of the side, but in the other shapes the samples were taken from the upper corners, that is, the corners which would later make the upper corners of the head, and for the diagrams I have used the average of the two upper corner results. The bloom

was not a normal one, as it had been placed on its side to cool immediately after stripping, but it is entirely probable that the corners were set when this was done and probably the results may be used along with the others for the present comparison. I could not, however, use the interior results from this bloom. The diagrams of the second forming and the finishing passes show results from the center of the head, which would represent metal originally between the axis and the wall of the ingot, although the results can probably be taken as approximating the axial metal. On the diagrams showing the second forming pass, I have also shown the results from the base as an interesting comparison.

Considering now the various diagrams, Figs. 17 to 24, inclusive, it will be noticed that the metal of the ingot is fragile, having a low tensile strength (below 50,000 lbs. per sq. in.), and but little stretch. Passing on to the bloom, Fig. 18, where the metal has been reduced from about 400 sq. in. at the bottom of the ingot to about 60 sq. in. in the bloom, it will be noticed that the metal at the corners of the bloom has acquired

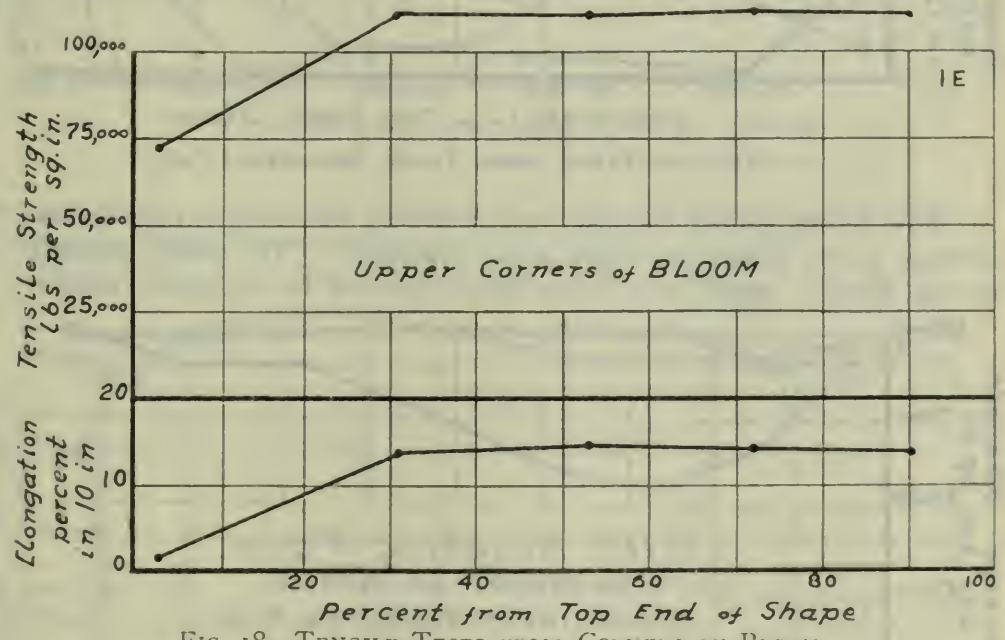


FIG. 18—TENSILE TESTS FROM CORNERS OF BLOOM.

a tensile strength of about 110,000 lbs. per sq. in., and an elongation of about 14 per cent. in 10 inches, except the sample from the top end of the bloom, which showed weak and brittle. Unfortunately, we have no results of the interior metal in the normal bloom, but the results seem to show that the exterior metal acquires almost its full physical properties in its reduction to the bloom.

The tensile strength and elongation curves of the third roughing pass, Fig. 19, again show good physical properties of the metal from the upper corners of the head, except at the upper end of the shape, but the axial metal shows low strength and low elongation, except in

the lower quarter of the shape, where fair physical properties are shown. It is also interesting to note that the top end of the shape also shows fair properties at the axis. The curves of the fifth roughing pass, Fig.

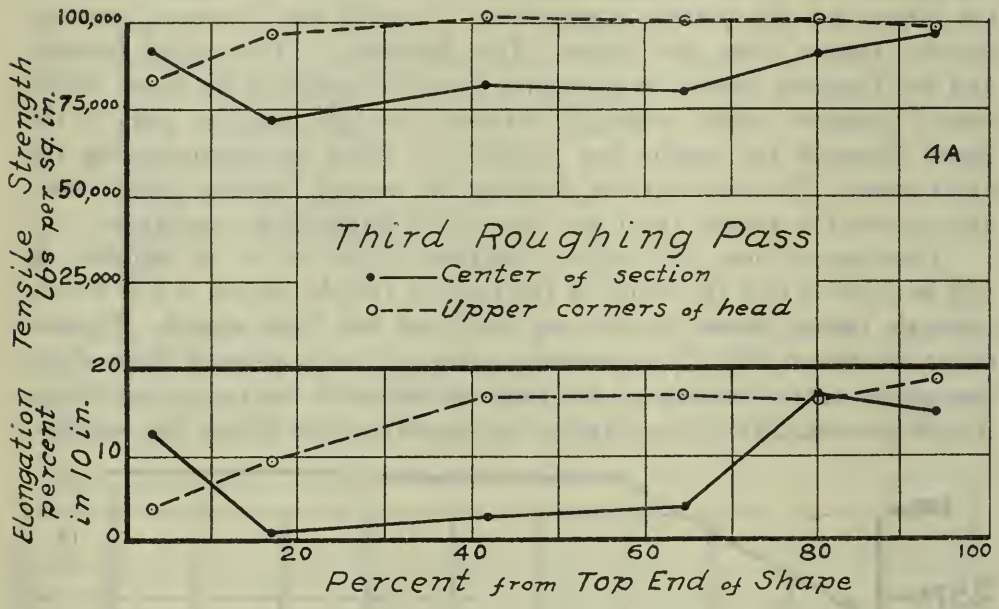


FIG. 19—TENSILE TESTS FROM THIRD ROUGHING PASS.

20, show results similar to those just described, but there is considerable increase in the elongation where it was low before. The tensile strength of the exterior metal also shows some increase in the upper quarter

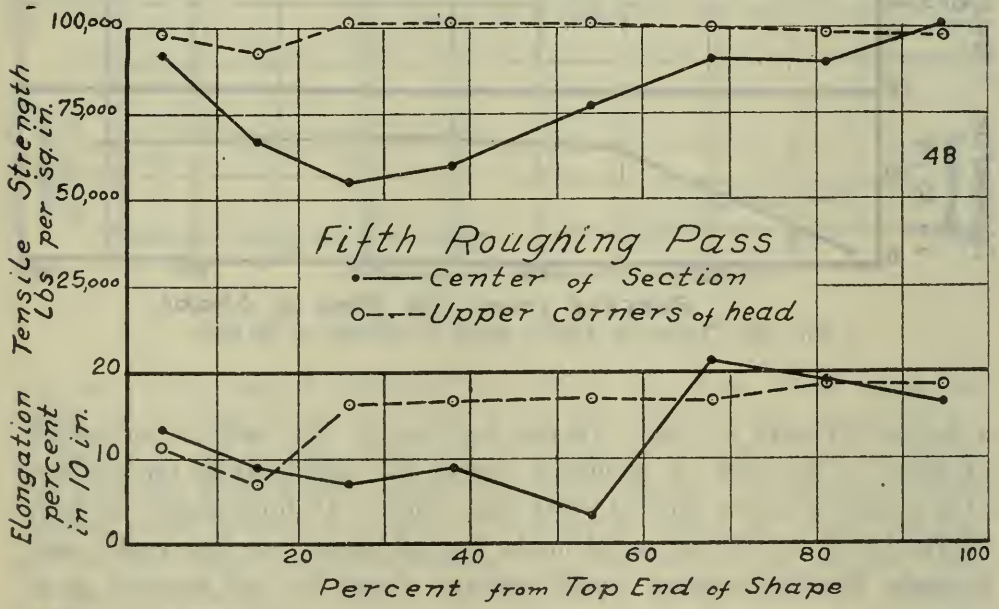


FIG. 20—TENSILE TESTS FROM FIFTH ROUGHING PASS.

of the shape, but the tensile strength of the axial metal has decreased in the region between 20 per cent. and 40 per cent. from the top end

of the shape. It is again interesting to note that the top end shows fair physical properties, this time across the whole section. In the squabbing pass, Fig. 21, there is considerable improvement of the tensile

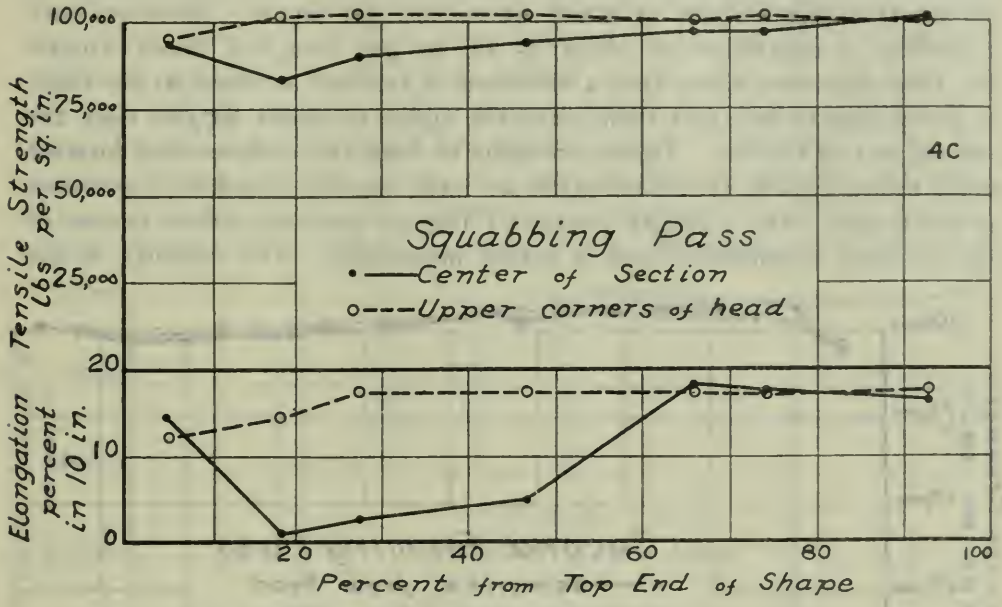


FIG. 21—TENSILE TESTS FROM SQUABBING PASS.

strength of the axial metal, but a drop in the elongation of this metal in the region between 20 and 60 per cent. from the top end.

The curves of the first forming pass, with an area of 14.1 sq. in.,

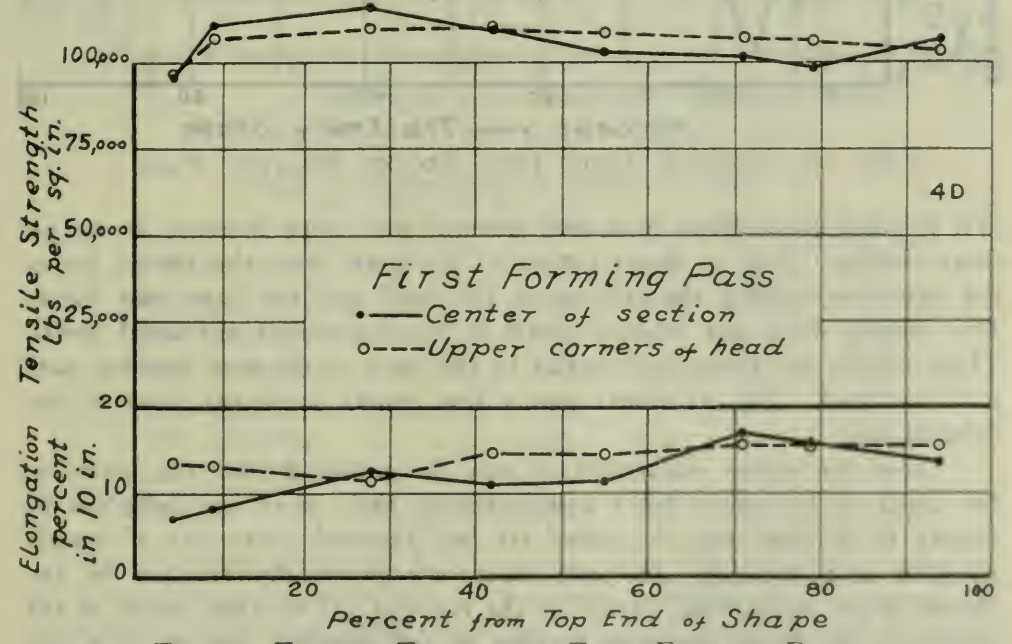


FIG. 22—TENSILE TESTS FROM FIRST FORMING PASS.

Fig. 22, are particularly interesting and should be studied closely, as we seem here to have developed almost the full physical properties of both

the exterior and interior metal. The tensile strength of the metal at the upper corners of the head is seen to first go up and then remain roughly even for the rest of the length of the bar. The strength of the interior metal starts at about 95,000 lbs. per sq. in., increases until it reaches a maximum at about 25 or 30 per cent., of about 116,000 lbs., then decreases again until a minimum is reached at about 80 per cent., of about 99,000 lbs., and then increases again to about 107,000 near the bottom end of the bar. These strengths of both the exterior and interior metal follow closely the distribution we have already found of the carbon in the bloom. The strength curves of Fig. 22 and the carbon curves of Fig. 10 have a similarity that is rather interesting. The ductility in the

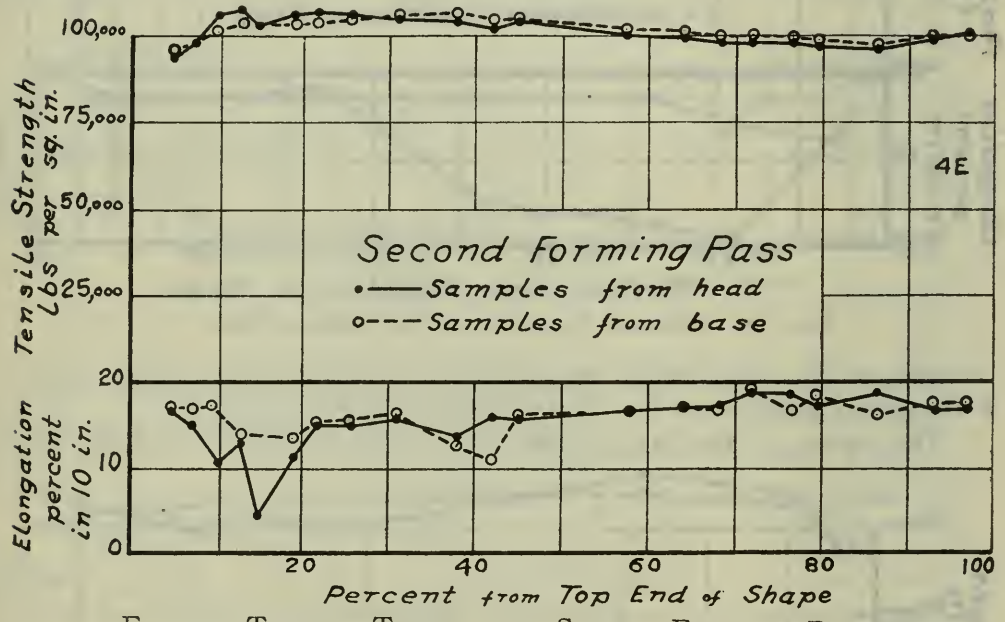


FIG. 23—TENSILE TESTS FROM SECOND FORMING PASS.

first forming pass shows in a very general way some increase as we go down the bar. Fig. 23 shows curves of the metal from the second forming pass representing the centers of the head and the base, and therefore mostly what was interior metal in the ingot, but not axial metal. These curves are somewhat similar to the ones of the first forming pass just discussed. Fig. 24 shows just a few results from the head of the finished rail.

From the above discussion it may be gathered that the metal in the walls of the ingot takes comparatively little work or reduction to impart to it what may be called its full physical properties of tensile strength and ductility. In fact, these are practically reached in the bloom at six reductions, except at the top end. The axial metal at the bottom of the ingot also soon reaches its full qualities, but in the upper half of the ingot it must be carried through the first forming pass or 25 reductions before this point is reached.

In order to show up somewhat more clearly the rate of improvement

of the physical qualities of the steel as the process of reduction proceeds, the tensile properties have been plotted on the basis of times reduced; that is, the ratio of the area of the original cross section of the ingot to the area of the shape. For this purpose four distances in per cent. from the top end have been selected as typical of the different regions to be found in the ingot, namely, 5 per cent., 25 per cent., 50 per cent. and 90 per cent. The times reduced in rolling at these distances for the different passes are shown in table 6 herewith. The expression, "times reduced," means the same as times elongated, and while perhaps not a strictly correct expression, its convenience probably justifies its use in this report, and its meaning will be the ratio above explained.

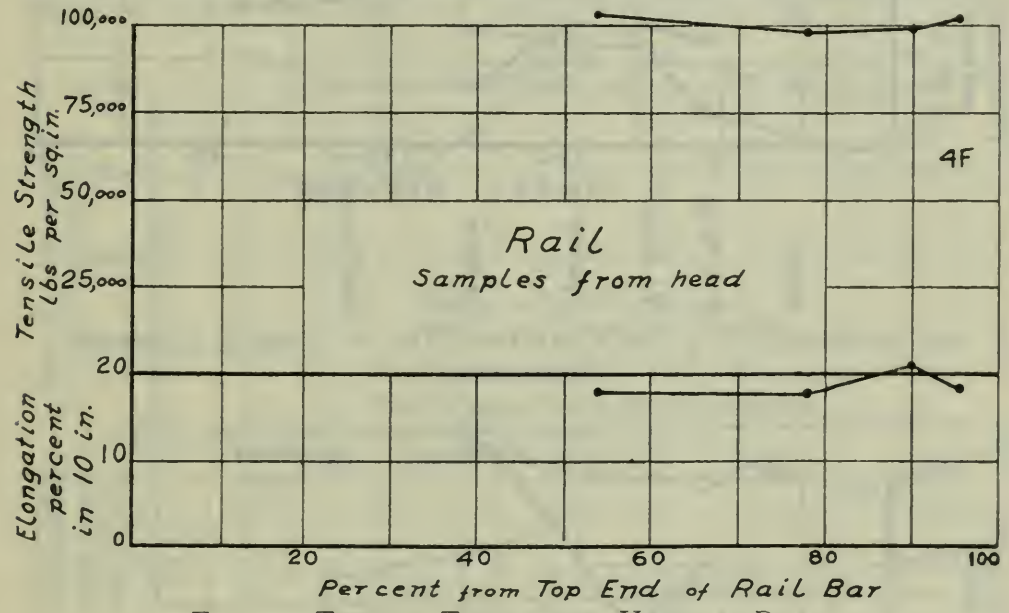


FIG. 24—TENSILE TESTS FROM HEAD OF RAIL.

TABLE 6—REDUCTIONS IN VARIOUS PASSES.

	Distance from top of shape.			
Pass.	5%	25%	50%	90%
Bloom	5.8	6.0	6.2	6.6
Third roughing	10.7	11.1	11.5	12.2
Fifth roughing	14.2	14.7	15.3	16.2
Squabbing	19.4	20.1	20.9	22.1
First forming	24.5	25.2	26.3	27.7
Second forming	31.9	33.1	34.3	36.2
Finishing	46.7	48.3	50.2	53.2

Fig. 25 shows the metal at 5 per cent. from the top of the ingot at the various stages of reduction. The metal originally in the corner of the ingot is weak and brittle until the stage of about 14 reductions is reached, while the axial metal reaches fair qualities somewhat sooner. The metal at 25 per cent. from the top end is shown in Fig. 26, and it will be noted that the exterior metal shows very fair qualities of

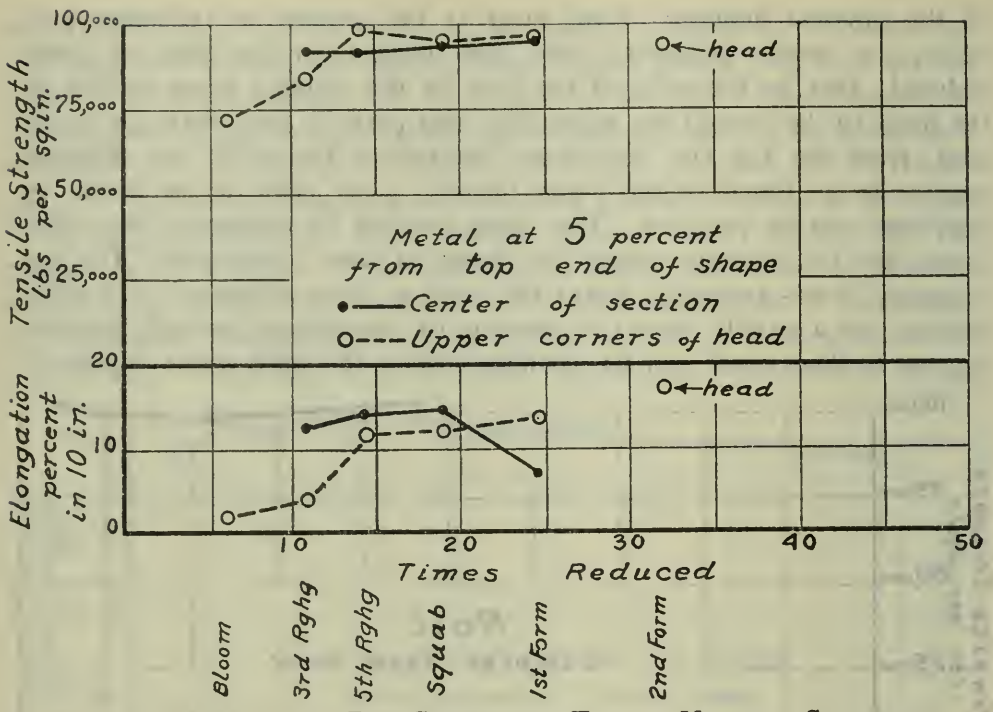


FIG. 25—METAL AT 5 PER CENT FROM TOP AT VARIOUS STAGES OF REDUCTION.

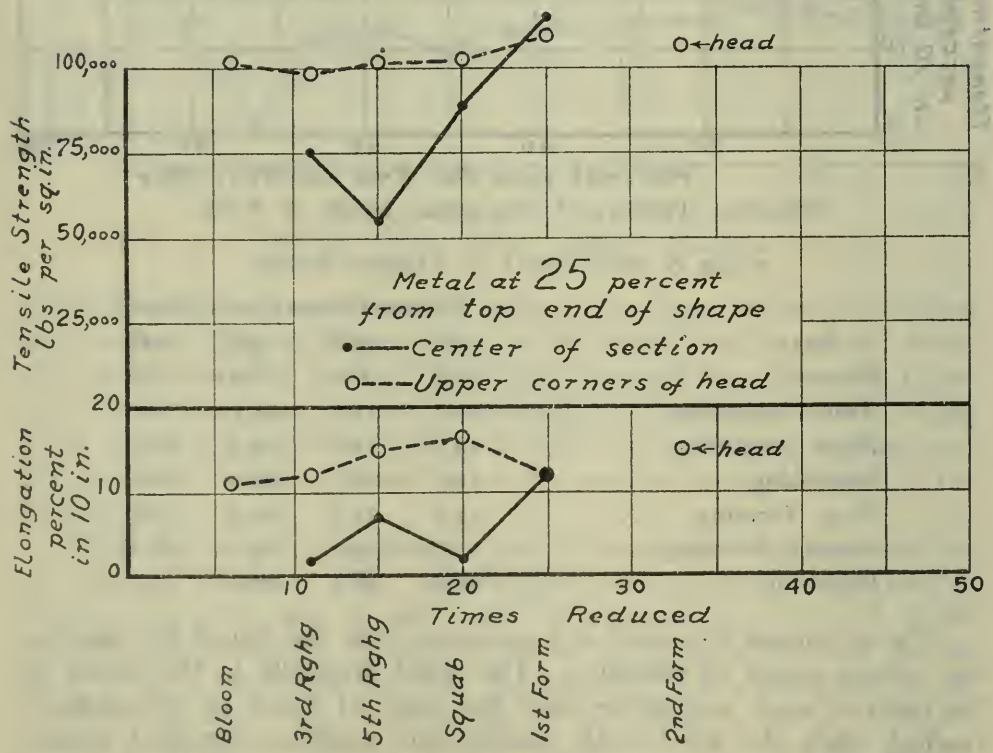


FIG. 26—METAL AT 25 PER CENT FROM TOP AT VARIOUS STAGES OF REDUCTION.

strength and ductility in the bloom at six reductions, and its full qualities are reached at about 20 reductions, showing a tensile strength of about 105,000 lbs. with about 16 per cent. elongation in 10 inches. The axial metal at 25 per cent. does not reach its full qualities until about 25 reductions is reached at the first forming pass, and even here the test pieces would contain some of the outer metal. Fig. 27 shows the metal at 50 per cent. and here the exterior metal shows good qualities from the bloom on with but little, if any, improvement beyond this stage, but the axial metal does not reach its full qualities until over 25 reductions is reached in the first forming pass or beyond. Fig. 28 shows the metal at 90 per cent., and here again the exterior metal shows its full

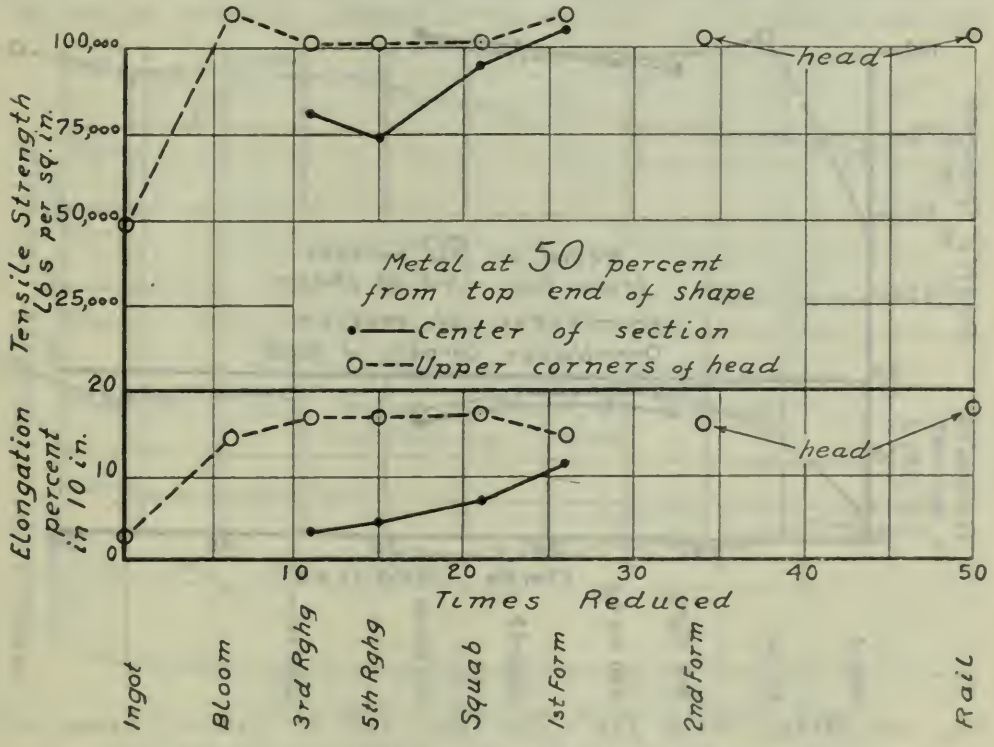


FIG. 27—METAL AT 50 PER CENT FROM TOP AT VARIOUS STAGES OF REDUCTION.

qualities in the bloom with but little or no improvement beyond this stage. The axial metal also shows its full qualities at the third roughing pass at twelve reductions. We have no results before this stage of reduction, which is unfortunate, as it would be very interesting to see whether the axial metal at the bottom of the ingot also reaches its full qualities in the bloom.

This study indicates that the metal in those portions of the ingot where it is of fairly even composition and free from sponginess, soon reaches its full physical qualities of tensile strength and ductility. Ten reductions, or a reduction to one-tenth of the original cross sectional area of the ingot, suffices, but the interior portion of the upper part of

the ingot requires 25 or more reductions to have its full qualities developed, that is, the original cross-sectional area of the ingot must be reduced below four per cent.

TENSILE TESTS OF RAILS.

Vol. 2 of Tests of Metals contains an interesting series of tensile tests of samples from the head of the rail bar from ingot D of heat 1, charged hot and soaked in the usual manner. The test specimens were .798 in. diameter with a sectional area of .5 sq. in. and a gage length of 10 in., and were taken along the whole length of the rail bar, from the middle of the head. The results of the tensile tests are collected

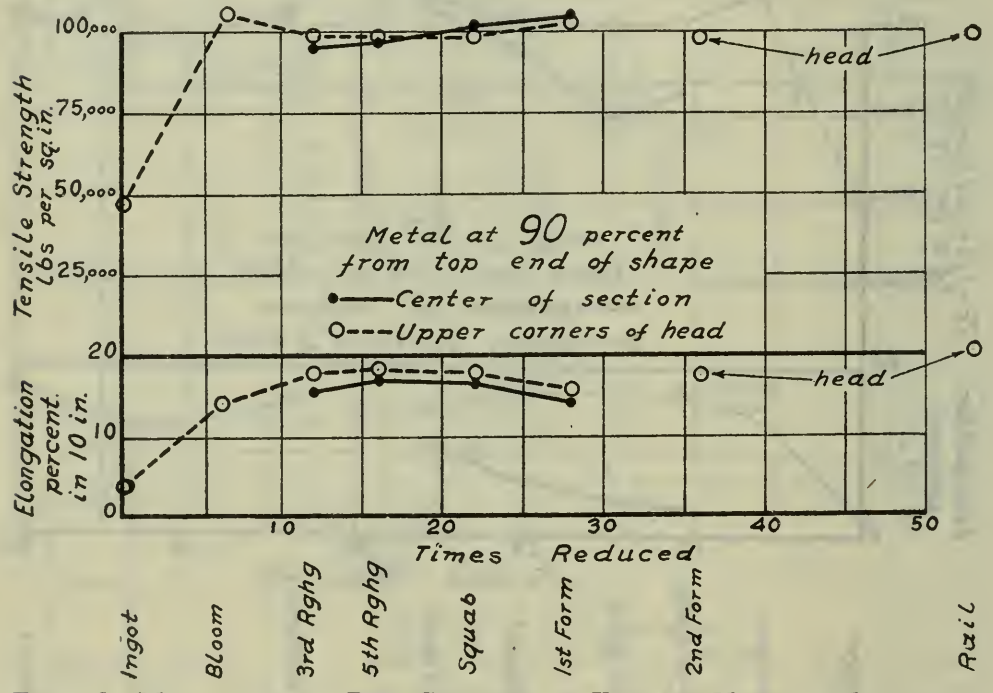


FIG. 28—METAL AT 90 PER CENT FROM TOP AT VARIOUS STAGES OF REDUCTION.

on pages 485 and 486, and I have plotted the tensile strength and elongation in Fig. 29 herewith on the basis of per cent. of distance from the top end of the rail bar. It will be noted that starting with a tensile strength of about 107,000 lbs. per sq. in. at 6 per cent., the strength rapidly goes up until a maximum of about 129,000 lbs. is reached at 14 per cent. The strength then gradually drops until a minimum is reached of about 102,000 lbs. at 86 per cent., after which it rises again, reaching about 111,000 lbs. near the bottom end of the bar. The elongation in 10 in. starts at 12 per cent., reaches a minimum of 8 per cent. where the tensile strength is greatest, and then gradually increases until 18 per cent. is reached at about 82 per cent. from the top, after which it again drops somewhat.

In this series of tests, then, we again find a distribution of the tensile properties along the bar, corresponding in a general way to the distribution found of the carbon in the interior of the bloom.

A similar series of tensile tests from the head of the rail was made of ingot F of heat 1, which was laid on its side to cool immediately after stripping, head side up, and then reheated. With an ingot kept in the usual vertical position there is a concentration of carbon, phosphorus and sulphur and of blow holes, in the interior and upper part of the ingot, and the effect of placing the ingot on its side to cool immediately after stripping and while the interior is still liquid, would be, it would seem, to orient the above-mentioned condition along almost the whole of the side uppermost in cooling, in this case, into the head of the rail for most of the length of the rail bar. The results of the tests

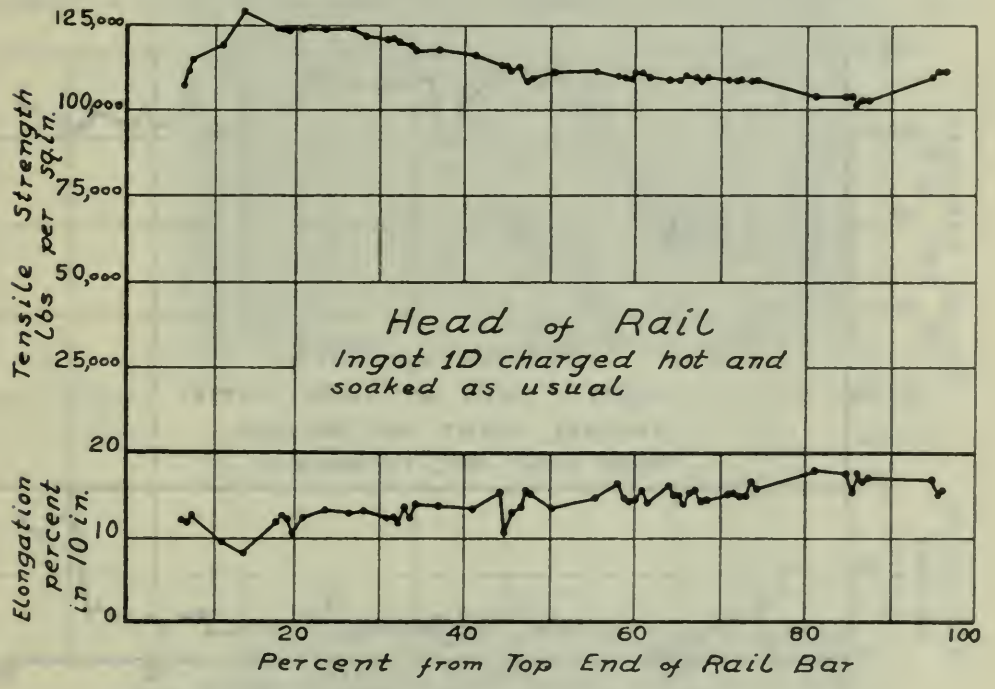


FIG. 29—TENSILE TESTS FROM HEAD OF NORMAL RAIL.

are shown on pages 551 and 552 of Tests of Metals, and I have plotted these in Fig. 30 herewith in the same manner as the previous results. At 6 per cent. from the top of the rail bar the results are a good deal the same as in the normal rail, but the elongation at once decreases, and the tensile strength soon follows, so that at 20 per cent. the ductility is practically all gone and the tensile strength down to 70,000 lbs. per sq. in. The tensile strength again goes up quickly, but afterwards varies considerably between about 98,000 and 121,000 lbs. per sq. in. The elongation also remains low, varying mostly between 2 and 6 per cent. until about 89 per cent. is reached, when it is about the same as in the normal rail for the rest of the rail bar, namely, above 15 per cent. The tensile strength is also about normal for the bottom 10 per cent.

These tests show, then, that the effect of placing the ingot on its side to cool immediately after stripping, head side up, is to render the metal in the head generally weak and brittle in tensile test, except for about 10 *per cent. from each end of the rail bar, where the metal exhibits its normal properties, due, presumably, to having set previous to stripping.*

ETCHINGS OF CROSS SECTIONS.

The Tests of Metals contains a great many most excellent reproductions of iodine etched cross sections of shapes from the ingot to the finished rail, showing the progressive change both from one end to the other of the ingot or bar, and also through the various passes. Starting from the top end of a shape, the structure as developed by etching

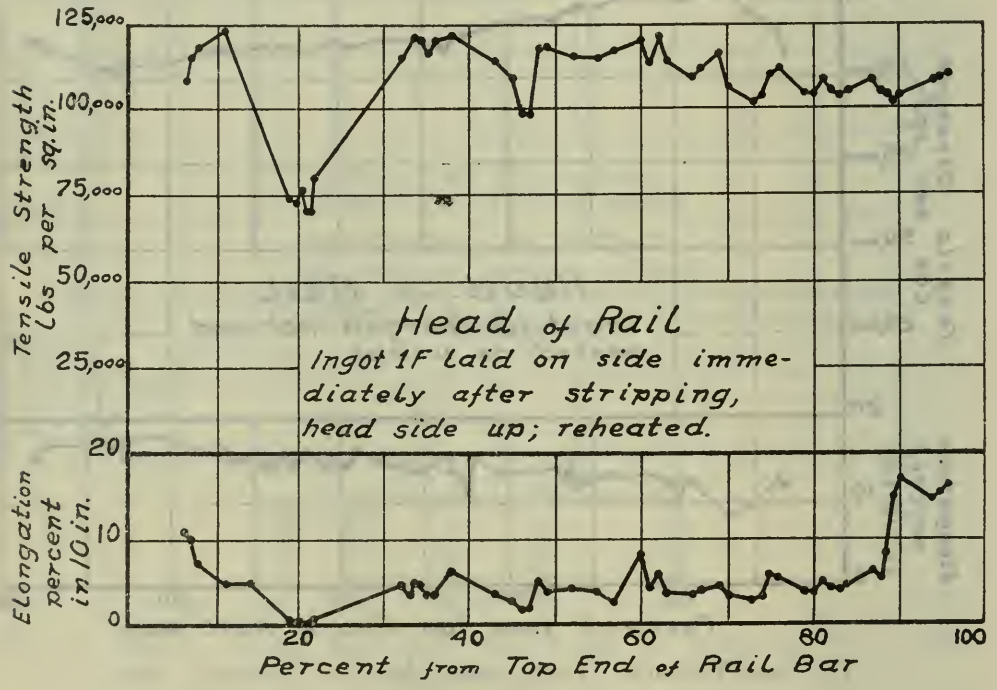


FIG. 30—TENSILE TESTS FROM HEAD OF RAIL MADE FROM AN INGOT THAT HAD BEEN LAID ON ITS SIDE TO COOL IMMEDIATELY AFTER STRIPPING, HEAD SIDE UP, AND REHEATED.

progressively changes to the bottom end, and each region has its characteristic structure. The various structures can, perhaps, be fairly well represented by distances of 10, 20 and 65 per cent. from the top end of the shape. At 10 per cent. the larger sections contain cavities of various sizes, distributed throughout the section, while the smaller sections show spots with a somewhat similar distribution, but more numerous. At about 20 per cent. all passes, except, perhaps, the largest sections, show a dark "core" with some dark spots distributed around. In the lower part of the shape, as typified by sections at about 65 per cent.,

the sections also show a core, but it is apt to show light. This lighter colored core first shows up about half way down, increasing in area until a distance of about 90 per cent. from the top end is reached, when the cross section becomes almost structureless on etching.

Figs. 31 to 56, inclusive, are given to show the progressive changes through the different passes for distances of about 10, 20 and 65 per cent. from the top end of the shape, and table 7 (page 40 of this report) shows the pages of Tests of Metals, 1909, from which these are reproduced.

FIG. 31—QUARTER INGOT, CROSS SECTION SLICE 1 B 4, 11.26% BY DISTANCE, 10.4% BY VOLUME, FROM TOP OF INGOT.

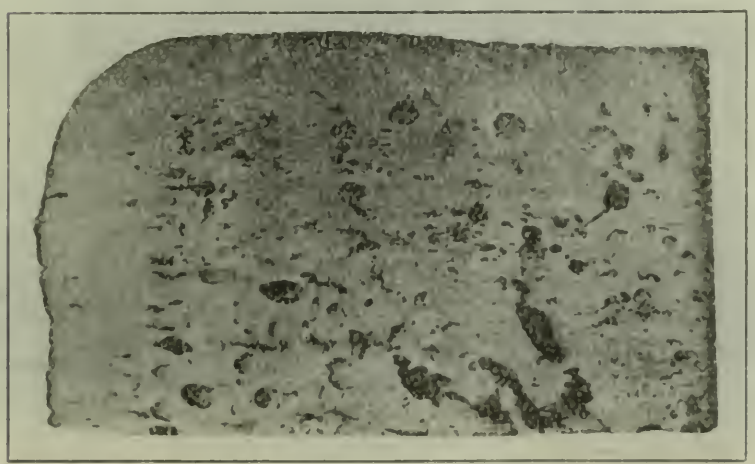


FIG. 32—SIXTH BLOOMING PASS, QUARTER SECTION 5 B 4—10.3% FROM TOP OF INGOT.

FIG. 33—NINTH BLOOMING PASS, QUARTER SECTION 5 C 3—9.1% FROM TOP OF INGOT.

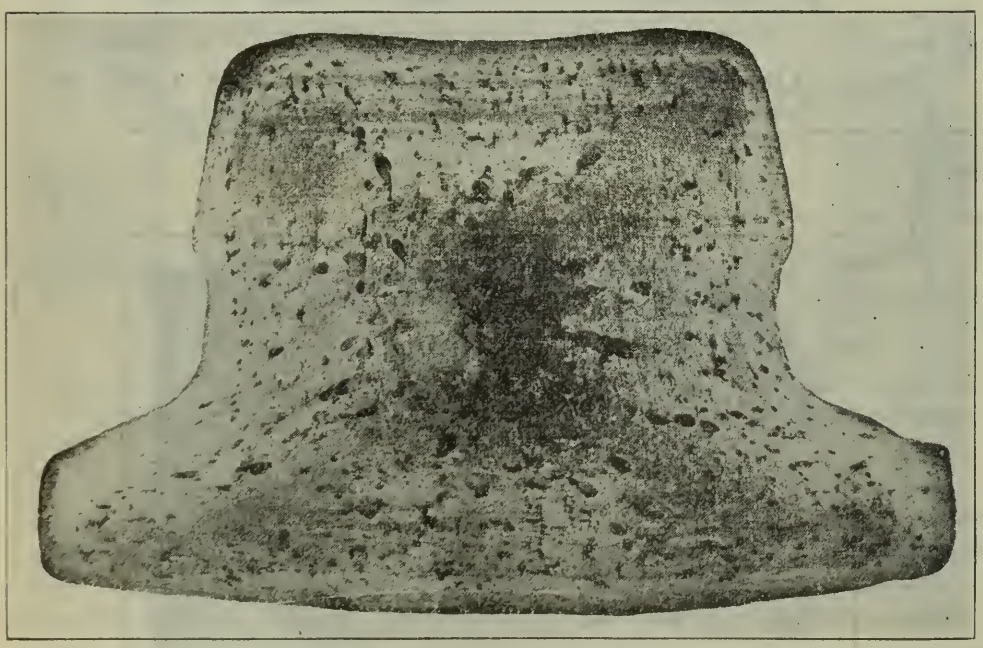


FIG. 34—THIRD ROUGHING PASS, CROSS SECTION SLICE 4 A 8—14.47% FROM TOP END OF SHAPE.

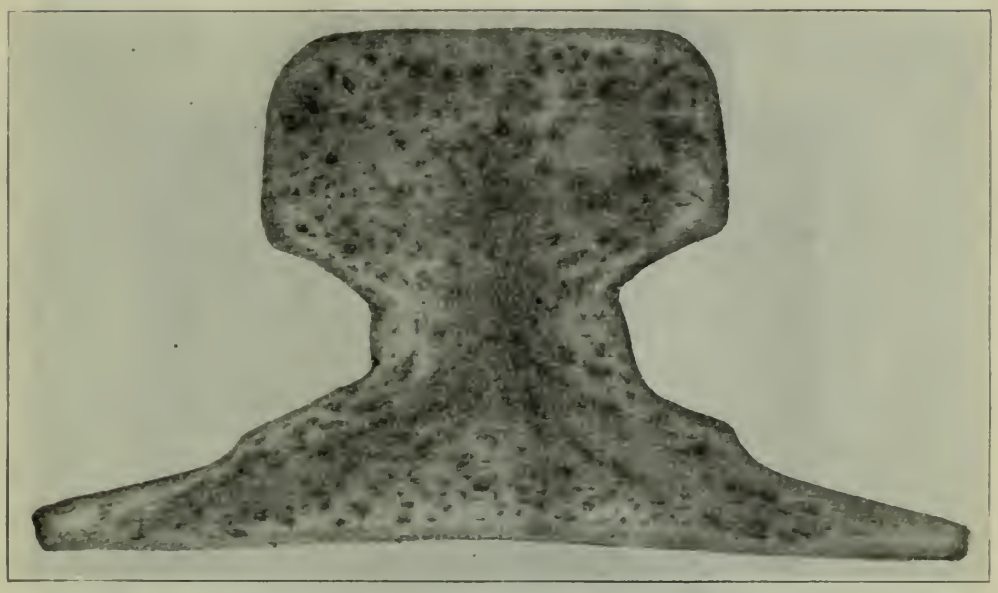


FIG. 35—SQUABBING PASS, CROSS SECTION SLICE 4 C 8—8.84% FROM TOP END OF SHAPE.

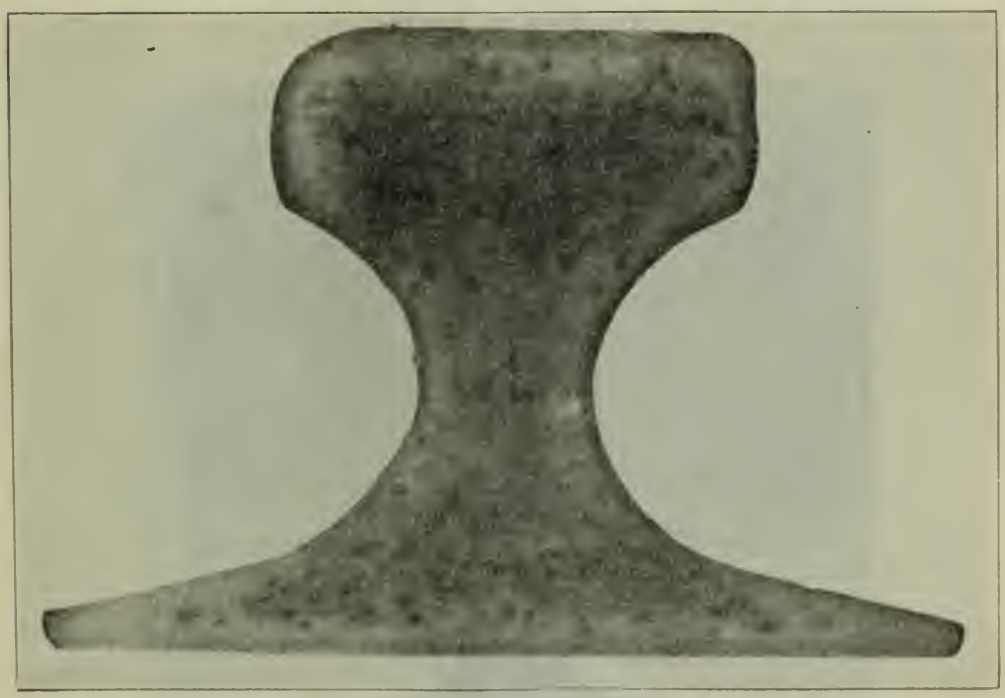


FIG. 36—FIRST FORMING PASS, CROSS SECTION SLICE 4 D 12—0.89% FROM TOP END OF SHAPE.

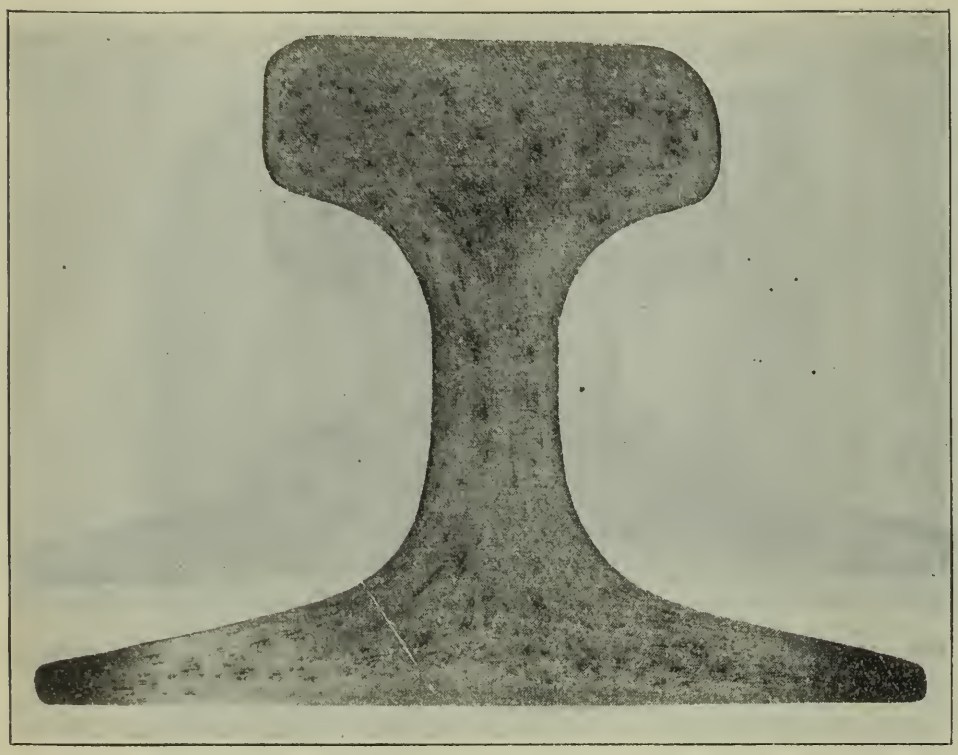


FIG. 37—SECOND FORMING PASS, CROSS SECTION SLICE 4 E 14—9.69% FROM TOP END OF SHAPE.

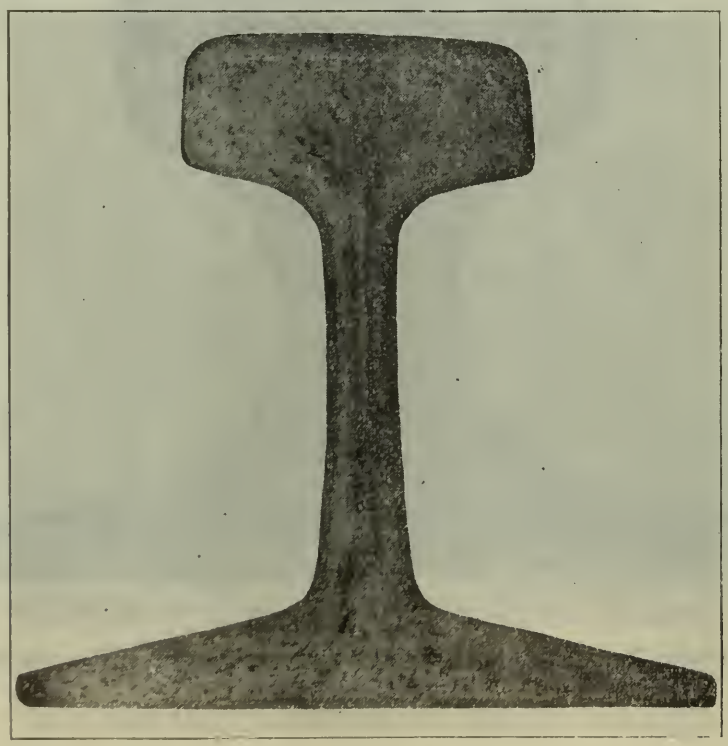


FIG. 38—75-LB. RAIL, CROSS SECTION SLICE 4 F 16—9.89% FROM TOP END OF RAIL BAR.

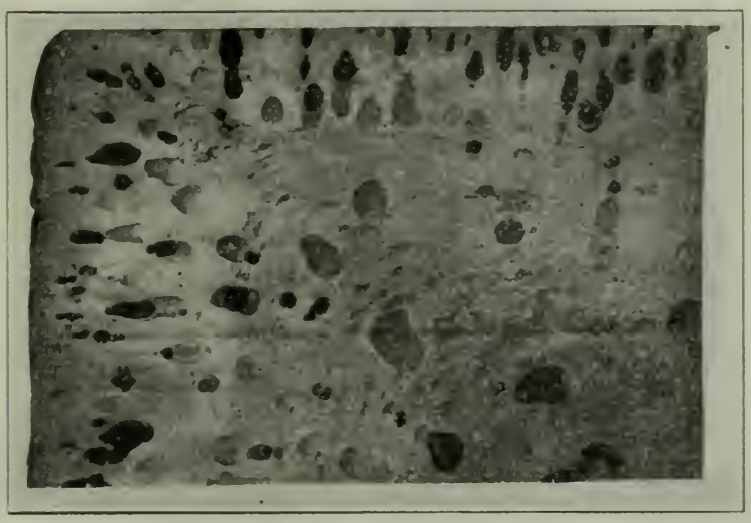


FIG. 39—QUARTER INGOT, CROSS SECTION SLICE 1 B 8—23.79% BY DISTANCE, 22.2% BY VOLUME FROM TOP OF INGOT.

FIG. 40—SIXTH BLOOMING PASS, QUARTER SECTION 5 B 7—20.2% FROM TOP OF INGOT.

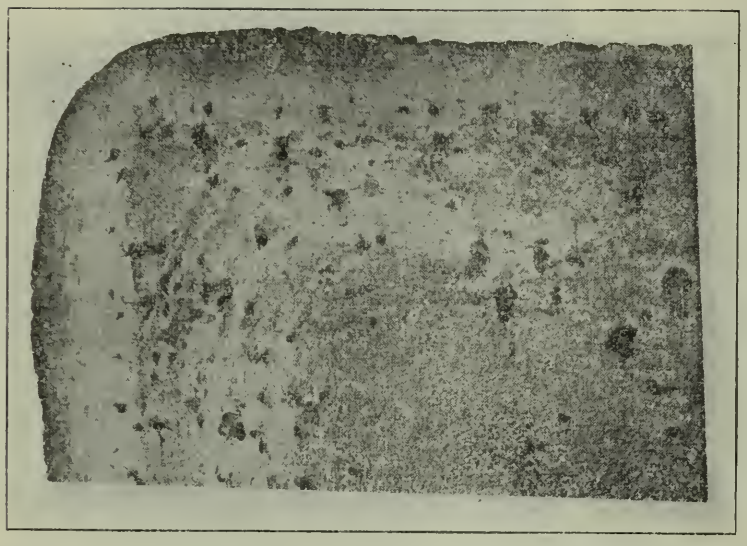


FIG. 41—NINTH BLOOMING PASS, QUARTER SECTION 5 C 11—21.6% FROM TOP OF INGOT.

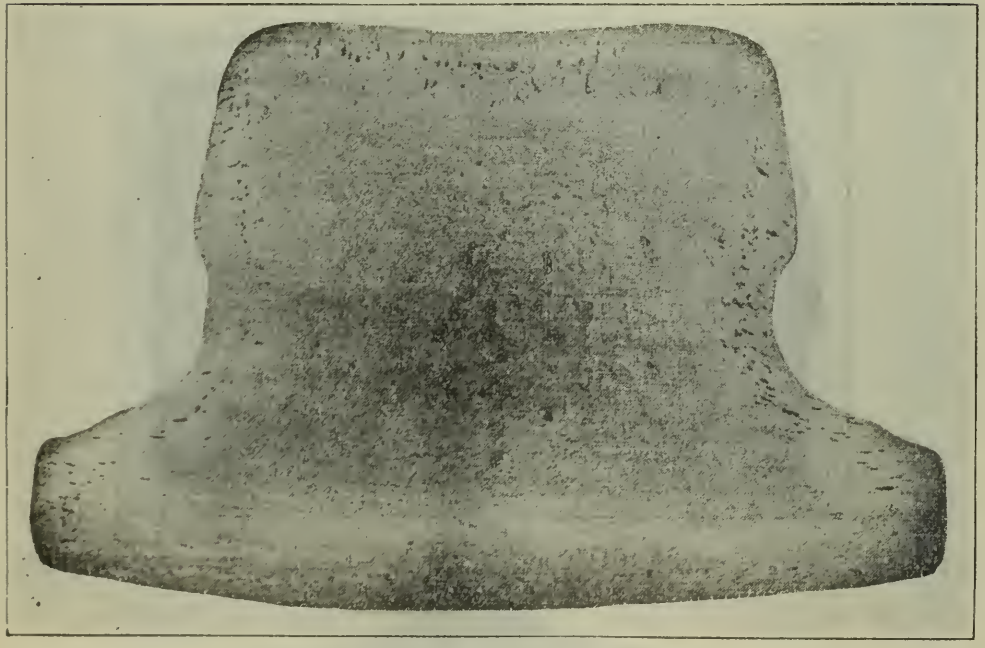


FIG. 42—THIRD ROUGHING PASS, CROSS SECTION SLICE 4 A 16—24.72% FROM TOP END OF SHAPE.

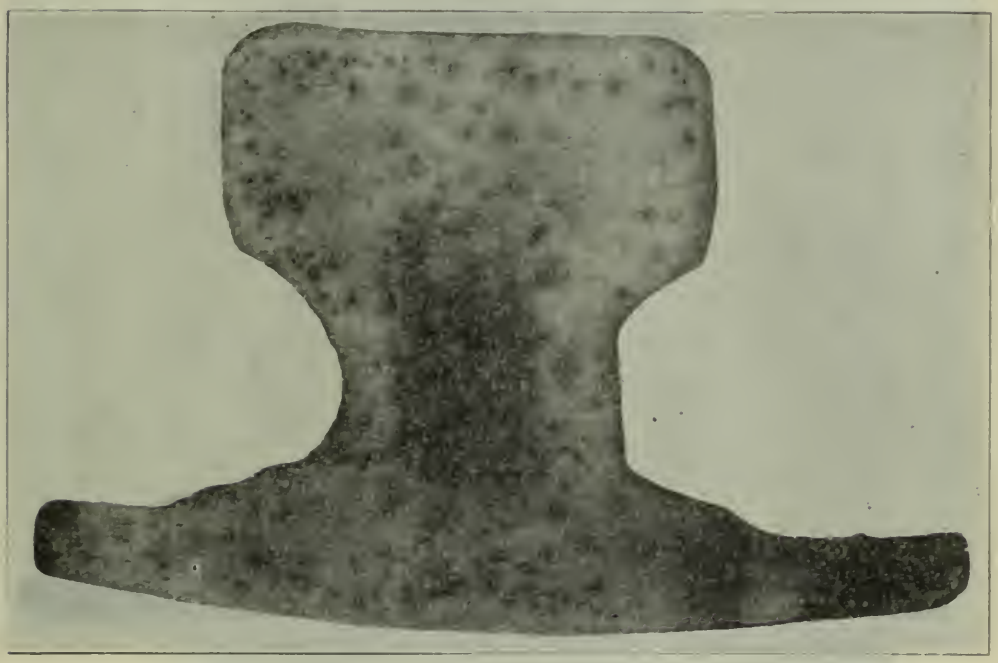


FIG. 43—FIFTH ROUGHING PASS, CROSS SECTION SLICE 4 B 16—17.04% FROM TOP END OF SHAPE.

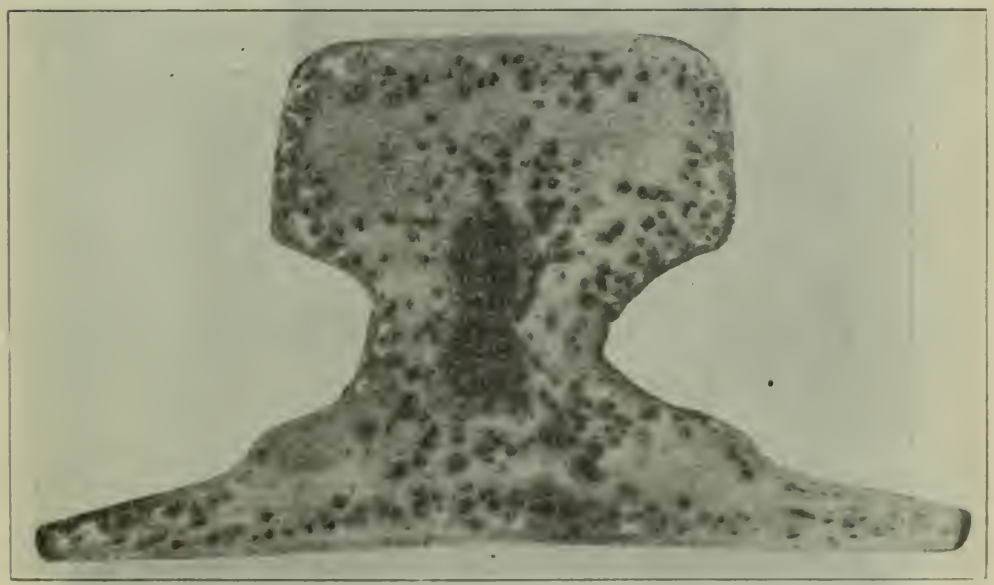


FIG. 44—SQUABBING PASS, CROSS SECTION SLICE 4 C 16—10.77% FROM TOP END OF SHAPE.

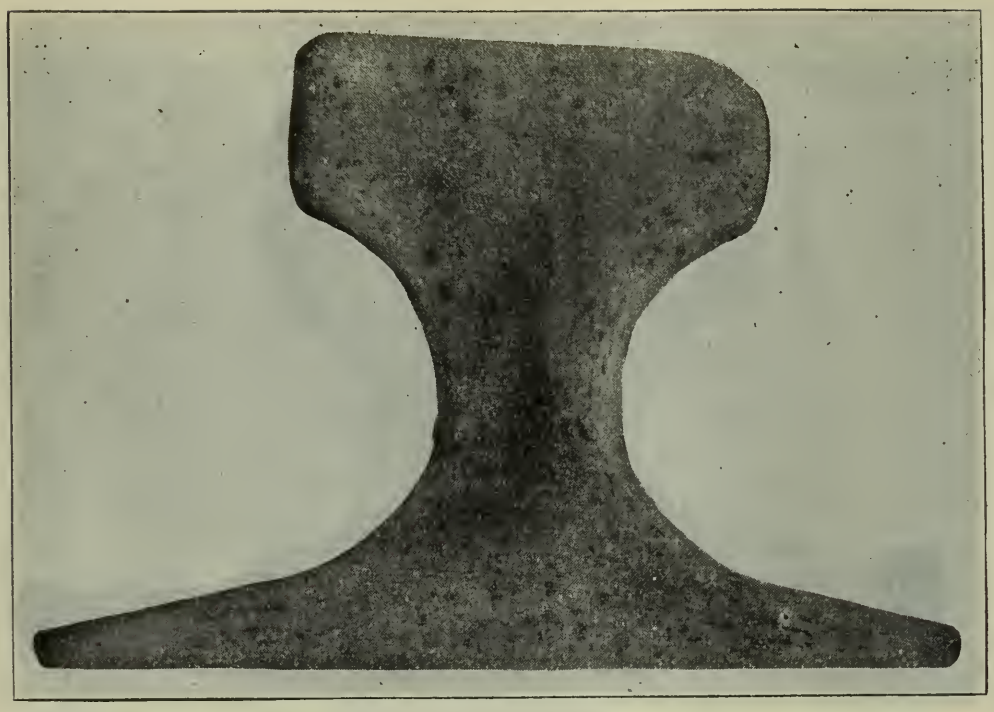


FIG. 45—FIRST FORMING PASS, CROSS SECTION SLICE 4 D 30—19.62% FROM TOP END OF SHAPE.

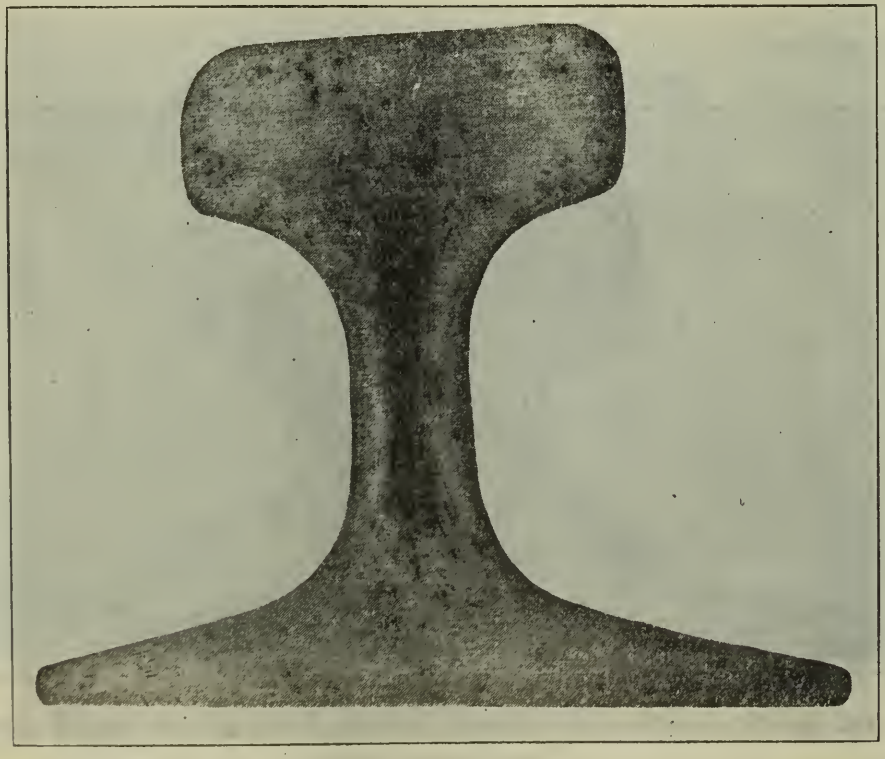


FIG. 46—SECOND FORMING PASS, CROSS SECTION SLICE 4 E 44—21.85% FROM TOP END OF SHAPE.

FIG. 47—75-LB. RAIL, CROSS SECTION SLICE 4 F 41—21% FROM TOP END OF RAIL BAR.

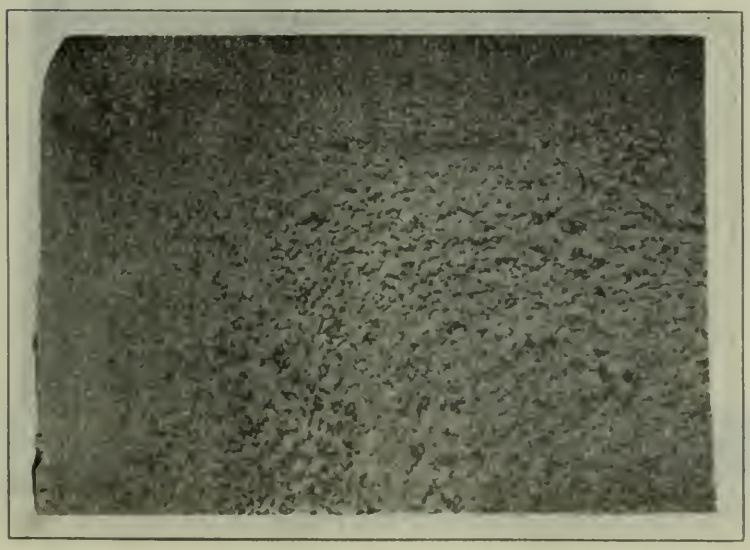


FIG. 48—QUARTER INGOT, CROSS SECTION SLICE 1 B 22—67.64% BY DISTANCE, 65.7% BY VOLUME, FROM TOP OF INGOT.

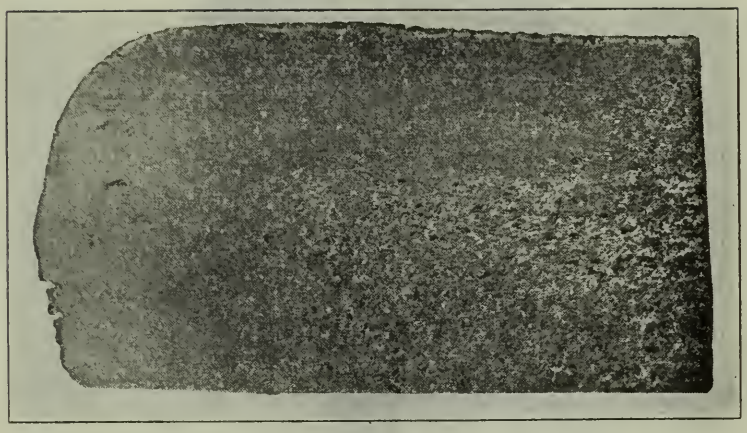


FIG. 49—SIXTH BLOOMING PASS, QUARTER SECTION 5 B 21—63% FROM TOP OF INGOT.

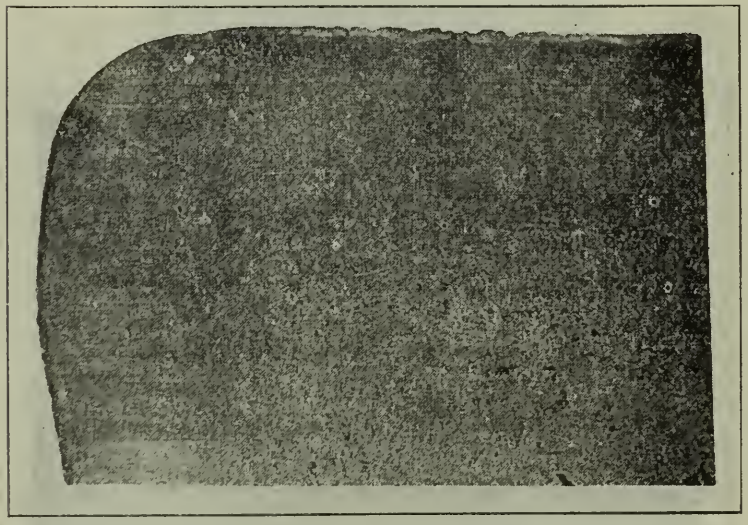


FIG. 50—NINTH BLOOMING PASS, QUARTER SECTION 5 C 37—62% FROM TOP OF INGOT.

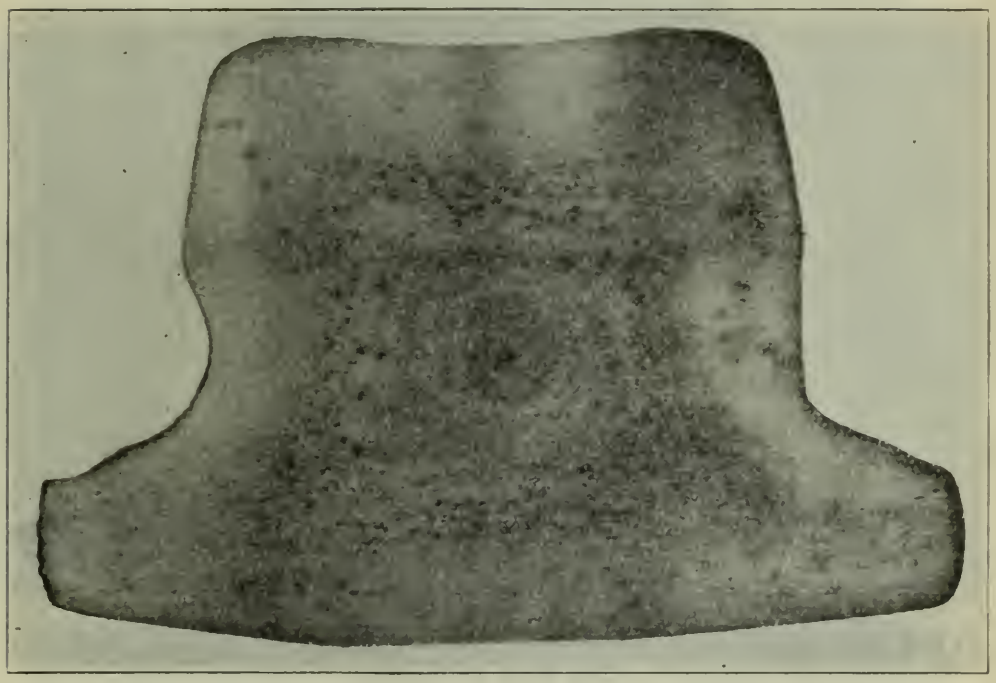


FIG. 51—THIRD ROUGHING PASS, CROSS SECTION SLICE 4 A 43—64.49% FROM TOP END OF SHAPE.

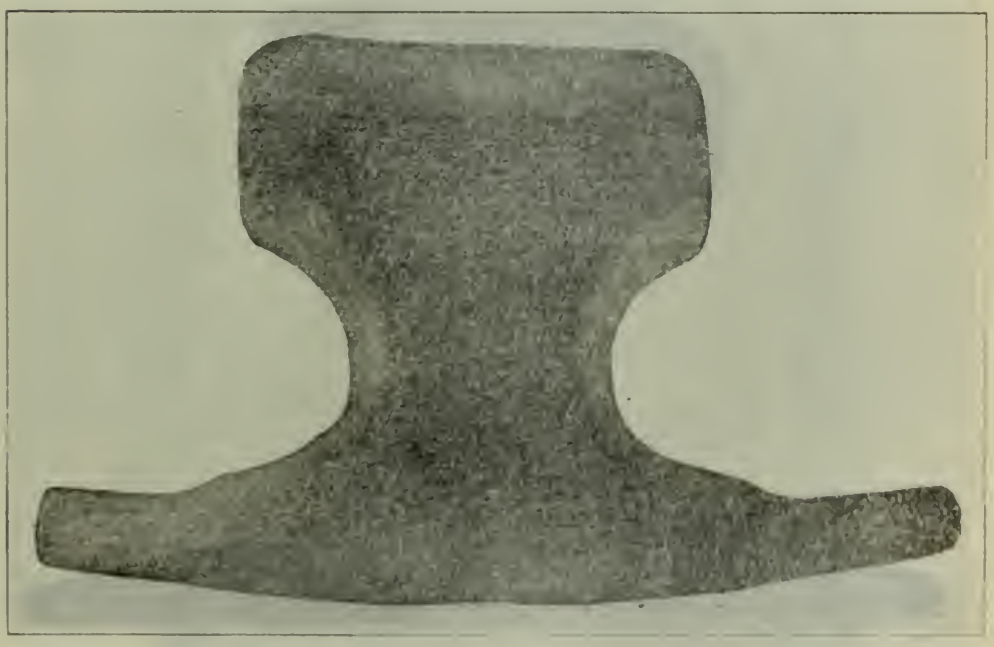


FIG. 52—FIFTH ROUGHING PASS, CROSS SECTION SLICE 4 B 60—67.52% FROM TOP END OF SHAPE.

FIG. 53—SQUABBING PASS, CROSS SECTION SLICE 4 C 83—73.43% FROM TOP END OF SHAPE.

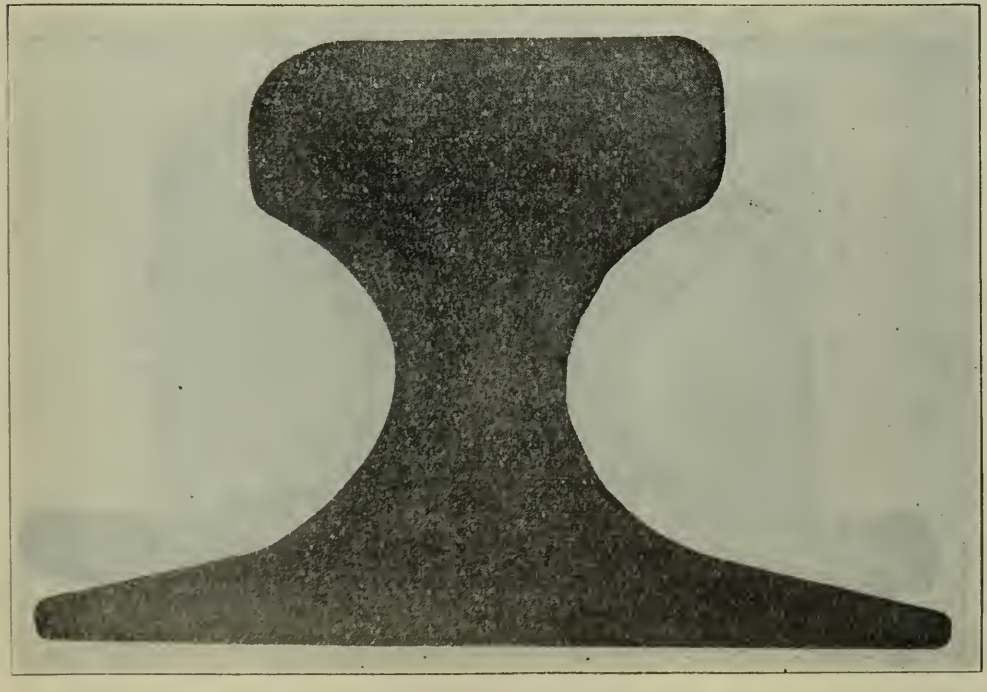


FIG. 54—FIRST FORMING PASS, CROSS SECTION SLICE 4 D 97—65.23% FROM TOP END OF SHAPE.

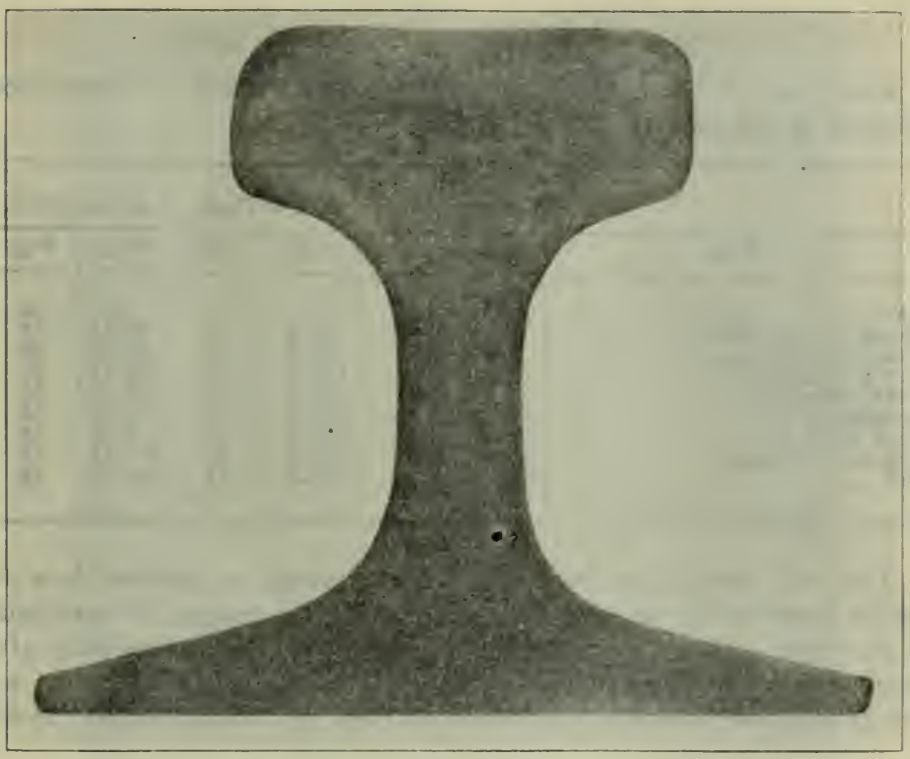


FIG. 55—SECOND FORMING PASS, CROSS SECTION SLICE 4 E 130—68.39% FROM TOP END OF SHAPE.

FIG. 56—75-LB. RAIL, CROSS SECTION SLICE 4 F 140—64.83% FROM TOP END OF RAIL BAR.

TABLE 7—PAGES OF TESTS OF METALS, 1909,

on which are shown etchings of cross sections, which are reproduced as figures of this report.

Pass.	10 Per Cent.		20 Per Cent.		65 Per Cent.	
	Page	Fig.	Page	Fig.	Page	Fig.
Ingot	23	31	27	39	41	48
Bloom, sixth pass	95-3	32	95-6	40	95-18	49
Bloom, ninth pass	99-1	33	99-7	41	99-20	50
Third roughing	165-3	34	165-5	42	165-11	51
Fifth roughing	.....	..	237-2	43	237-10	52
Squabbing	287-3	35	287-5	44	287-10	53
First forming	331-4	36	331-6	45	331-16	54
Second forming	371-2	37	371-6	46	371-13	55
Rail	575-2	38	575-4	47	575-13	56

The rails made from ingot 3F are interesting, as showing how the interior structure as developed by etching may be changed by manipulating the ingot. This ingot was laid on its side to cool immediately after stripping, web side up, and then reheated for 9 hours. Four etched sections of rails are herewith reproduced as Figs. 57 to 60, inclusive, at dis-

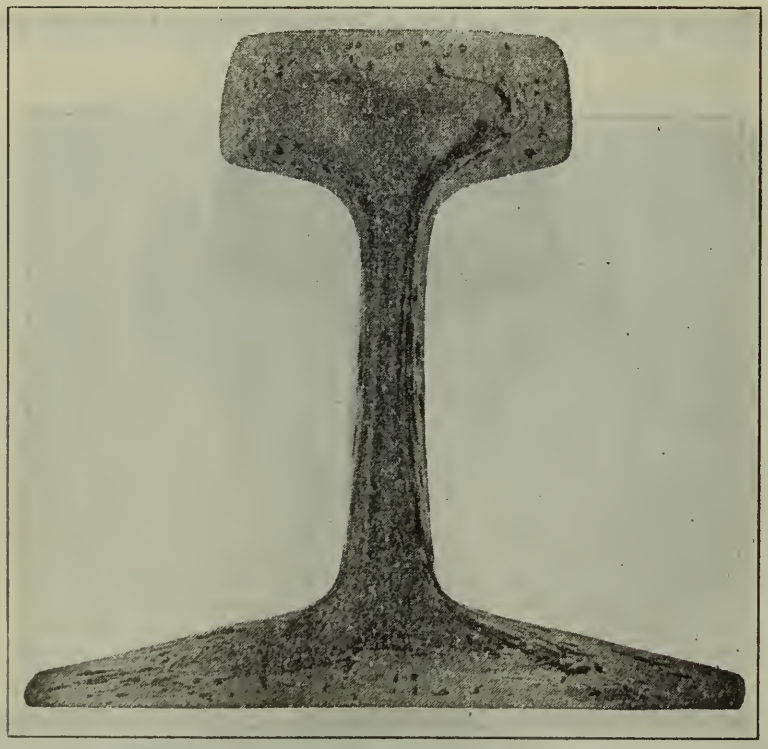


FIG. 57—75-LB. RAIL, CROSS SECTION SLICE 3 F 16—10.80% FROM TOP END OF RAIL BAR. INGOT LAID ON SIDE TO COOL, IMMEDIATELY AFTER STRIPPING, WEB SIDE UP.

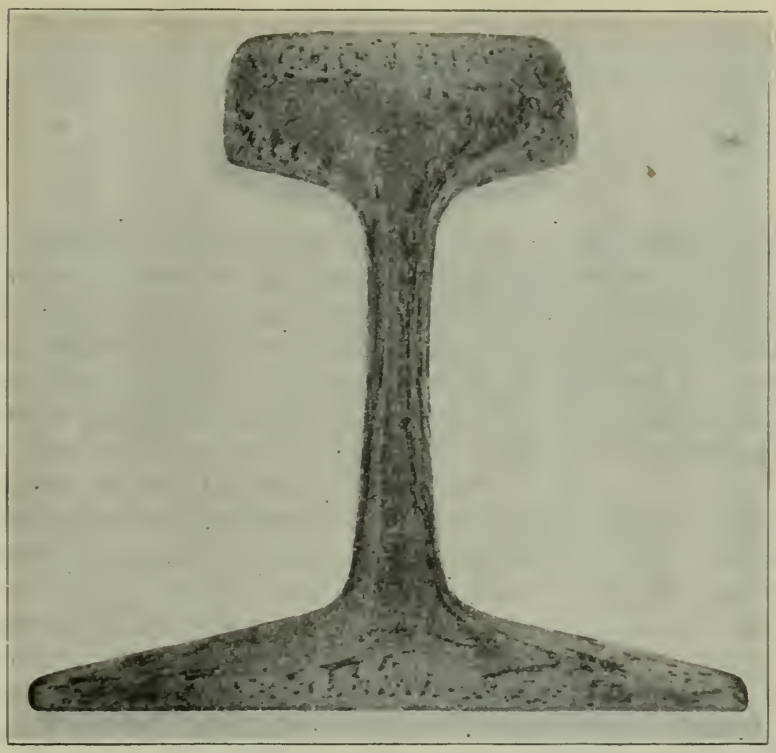


FIG. 58—75-LB. RAIL, CROSS SECTION SLICE 3 F 39—20.51% FROM TOP END OF RAIL BAR. INGOT LAID ON SIDE TO COOL, IMMEDIATELY AFTER STRIPPING, WEB SIDE UP.

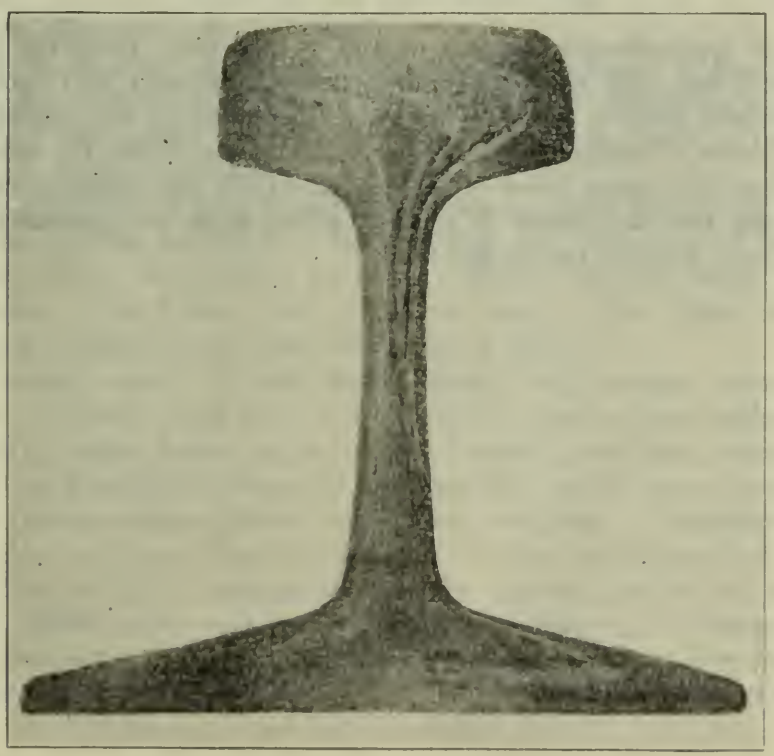


FIG. 59—75-LB. RAIL, CROSS SECTION SLICE 3 F 111—50.41% FROM TOP END OF RAIL BAR. INGOT LAID ON SIDE TO COOL, IMMEDIATELY AFTER STRIPPING, WEB SIDE UP.

FIG. 60—75-LB. RAIL, CROSS SECTION SLICE 3 F 173—74.71% FROM TOP END OF RAIL BAR. INGOT LAID ON SIDE TO COOL, IMMEDIATELY AFTER STRIPPING, WEB SIDE UP.

tances of approximately 10, 20, 50 and 75 per cent. from the top end of the rail bar, and it will be noted how the streaks and spots have been oriented toward the side that was uppermost in the cooling ingot. There is now a similarity of appearance along practically the whole bar, except that the upper third of the length of the bar shows some spots on the side that was below in cooling, which spots are generally absent in the lower part of the length.

SUMMARY.

1. The Report of Tests of Metals, etc., made at Watertown Arsenal, Mass., for the year 1909, is devoted largely to tests of rail steel ingots and derivative shapes. Etchings were made of sections of the ingot and of successive shapes to the finished rail, and the report consists largely of the illustrations of these etchings, showing the changes in structure from one end of a shape to the other, and through the successive shapes. Tensile test bars were also taken at successive stages of the rolling, and a carbon survey of two blooms is also given.

2. Below are given statements of the various conclusions that seem to be indicated by the tests as applying to the Bessemer steel dealt with in this investigation, and to the conditions under which it was made, and care should be exercised when applying them to other steel and other conditions of manufacture. The ingots were about 19½x20½ in. at the bottom and 5 ft. high.

3. Examination of ingots shows that the upper third of the ingot is very spongy, that is, it contains a great many cavities of various sizes. The sponginess, in general, tapers toward the center.

4. Examination of successive shapes shows that the larger central cavities persist well beyond the blooming passes, and that the sponginess extends downward from the top end of the shape about the same proportionate distance as in the ingot.

5. The cavities of a cold ingot, which had been placed in the soaking pit directly after stripping, and then cooled down, constitute a little larger part of the volume of the ingot than where the ingot is cooled down directly without soaking.

6. The cavities of a cold bloom made from an ingot which had been placed in the soaking pit directly after stripping, and rolled into a bloom upon removal from the soaking pit, also constitute a little larger part of the volume of the bloom, than where the ingot is first cooled down after pouring, reheated and then rolled into a bloom.

7. A carbon survey of two blooms shows that, starting from the top end of the bloom, the axis at first shows negative segregation of carbon, that is, carbon below the average in the steel, reaching a minimum at about 6 or 8 per cent. from the top, but the carbon soon increases and shows considerable positive segregation, reaching a maximum at about 22 or 24 per cent. from the top end. About half way down, the carbon at the axis again reaches the average amount, and in the lower half again shows some negative segregation, coming up to about the normal at the bottom. The maximum segregation of carbon was 70 per cent. in one bloom and 54 per cent. in the other, above the average content.

The walls of the upper part of the bloom show negative segregation of carbon, which rises until the average carbon content of the bloom is reached at about 25 or 35 per cent. from the top end. The greatest negative segregation was 32 per cent. in one bloom and 26 per cent. in the other, that is, the carbon was this much below the average content of the bloom.

8. Tensile tests were made of specimens taken at various stages from the ingot to the finished rail, and they throw light on the question of the amount of work or reduction necessary in rolling to develop the full physical qualities of the steel. The results indicate that the metal in the walls of the ingot takes comparatively little work or reduction to impart to it what may be called its full physical properties of tensile strength and ductility. These are reached in the bloom, except at the top end. The axial metal at the bottom of the ingot also soon reaches its full physical properties, but in the upper half of the ingot it must be carried well toward the finished rail before these properties are fully developed.

Where the metal is of fairly even composition and free from sponginess, it reaches its full physical qualities of tensile strength and ductility at about ten reductions or a reduction to one-tenth of the original cross section of the ingot, but the interior portion of the upper part of the ingot requires 25 or more reductions to have its full physical qualities developed, that is, the cross-sectional area must be reduced below 1/25 of its original amount.

9. Tensile tests were made of specimens taken from the center of the head of a rail bar which was made in the usual manner, and were taken along the whole length of the bar. The tensile strength corresponds, in a general way, with the distribution of the carbon in the interior of the bloom, that is, it first goes up as we go down the bar, reaching a maximum at 14 per cent. down, then the strength gradually drops until a minimum is reached at 86 per cent. down, after which it rises again. The maximum tensile strength in this bar was 129,000 lbs. per sq. in., and the minimum was 102,000 lbs. The elongation, in general, varied inversely as the strength between limits of 8 per cent. in 10 inches and 18 per cent.

10. A similar series of tensile tests was made on specimens from a rail bar made from an ingot that had been laid on its side to cool immediately after stripping, head side up, and then reheated. The effect of this treatment of the ingot is to render the metal of the head generally weak and brittle in tensile test, except for about 10 per cent. from each end of the rail bar, where the metal exhibits its normal properties.

11. Etchings were made of cross sections of shapes from the ingot to the rail, showing the progressive change from one end of the shape to the other, and also through the various passes. Each region along the length of the shape has its characteristic structure. Near the top end, the ingot and larger passes show holes generally distributed, while the smaller passes show spots and streaks on etching. About one-fifth

or one-fourth way down, the sections, particularly the smaller ones, show a dark core with a few spots and streaks. The cross sections from the bottom half of the shapes also show a core, but entirely different in appearance, and it generally shows lighter colored. Each structure finds its counterpart in the succeeding shapes and at about the same proportionate distance from the top end.

12. Among the illustrations are etchings of cross sections of a rail bar made from an ingot that had been laid on its side to cool immediately after stripping, web side up, and then reheated. This treatment of the ingot changes the structure entirely and its effect is to orient the spots and streaks along the side that was uppermost in cooling and for most of the length of the rail bar.

Appendix E.

INFLUENCE OF ROLLING TEMPERATURE ON THE PROPERTIES OF BESSEMER RAILS

By

M. H. Wickhorst, Engineer of Tests, Rail Committee.

This report covers an investigation to throw light on the influence of the rolling and finishing temperature on the properties of Bessemer steel rails. A series of five ingots, all of the same heat, were rolled into 85-lb. rails, all in the same manner except as to temperature of rolling. A range of temperature was used from "cold" rolling to very hot rolling, corresponding to shrinkages in a 33-ft. rail, varying from an average of 6¼ in. on the first rail-bar to an average of 7 in. on the last rail-bar. The rails were then examined by means of drop, tensile and microscopic tests and in addition an ingot of the same heat was split open and a chemical survey made of it. The rails were made at the Edgar Thomson Works at Braddock, Pa., of the Carnegie Steel Company, who kindly furnished a heat of steel and all the means and facilities involved in carrying out the tests, and the thanks of the Committee are due to the various officers of the Carnegie Steel Company for their kindness and the efficient manner in which the work was carried out.

MANUFACTURE.

The steel used was Bessemer steel made from Lake Superior ores. The iron from the blast furnaces was poured into a mixer from which it was weighed, poured into the converter and blown, scrap steel being added at the same time. After blowing, the metal was poured into the teeming ladle, the spiegel, in liquid condition, being poured in at the same time, and the mixture was then poured into the molds. The amounts of materials used to make this heat (No. 4,824 of August 24, 1911) are shown in table 1.

TABLE I—BESSEMER AMOUNTS.

Mixer metal	30,600	lbs.
Scrap steel	2,500	"
Spiegel	3,280	"
Total	36,380	"

Analyses of special samples of the mixer metal and spiegel and of the regular heat sample, taken about the middle of the heat, gave the results shown in Table 2.

TABLE 2—ANALYSES.

	C.	P.	S.	Mn.	Si.
Mixer metal.....	4.27	.089	.060	.62	1.38
Spiegel	4.20	.099	.014	10.52	1.50
Heat sample.....	.487	.095	.067	1.10	.19

(I was told that the mixer metal generally contained less carbon than shown above, and it was conjectured that this sample may possibly have had an excess of graphite.)

The various Bessemer operations occurred at the times shown in table 3.

TABLE 3—TIMES OF BESSEMER OPERATIONS.

Date	Aug. 24, 1911
Started blowing.....	8.29 a. m.
Finished blowing.....	8.40 "
Time used to blow.....	11 min.
Started to pour into ladle.....	8.40 a. m.
Started to pour into molds.....	8.43 "
Time from finish of blowing to start of pouring into molds...	3 min.
Finished pouring into molds.....	8.52 a. m.

The heat made seven ingots and a "butt," six of which were used for the experimental work. The ingots were about 18½ in. by 19½ in. at the bottom, about 51 in. high and weighed about 4,400 lbs. each. After stripping, the ingots were placed in the soaking pit in a vertical position in the usual manner, and after soaking varying lengths of time were rolled into blooms about 9½ in. square in seven passes. The discard from the top of the bloom was as small as practicable to allow of satisfactory rolling. The bloom was cut in two, the two halves were placed in a reheating furnace and, when raised to the desired temperature, were rolled, without being held at any stage, into 85-lb. rails in 13 passes, as follows: seven roughing, five forming and one finishing pass, making a total of 20 passes from the ingot to the rail. Just before entering the finishing rolls, the rail-bar was flooded with strong jets of water to knock off the scale. The section used was the Pennsylvania Railroad System, 85-lb. P. S. section, illustrated on page 162, Vol. 12, part 2, 1911, Proc. Am. Ry. Engr. & M. W. A. Each ingot made four rails.

As stated, there were seven ingots in the heat. The first ingot of the pouring was not used for this test work and the fourth was used for splitting open and making a chemical survey. Ingots 2, 3, 5, 6 and 7 were given test numbers respectively as follows: ET6, ET7, ET8, ET9 and ET10, and were used for making rails for test. The fourth ingot

was given test number ET11. The six ingots were all placed in the soaking pit about the same time (about 9.50 a. m.), but drawn at different times, as the making of the test rails proceeded. The lengths of time they were in the soaking pit are shown in table 4.

TABLE 4—TIME IN SOAKING PIT.

Ingot	Time in Pit.	Used For.
ET6	1 hr. 29 min.	Rails
ET7	2 " 23 "	"
ET8	2 " 25 "	"
ET9	3 " 12 "	"
ET10	3 " 13 "	"
ET11	2 " 24 "	Splitting

The lengths of time that the pairs of blooms from each ingot were in the reheating furnace are shown in table 5.

TABLE 5—TIME IN REHEATING FURNACE.

Blooms from Ingot.	Time in Furnace.
ET6	30 min.
ET7	17 "
ET8	32 "
ET9	38 "
ET10	55 "

The temperatures of the various rail bars were determined after leaving the finishing rolls by means of a Thwing radiation pyrometer, the tube of the instrument being directed toward the top of the head of the rail. The shrinkages were also determined by measuring the saw settings and the rails after cooling. These temperatures and shrinkages are shown in table 6.

TABLE 6—SHRINKAGES AND FINISHING TEMPERATURES.

	Shrinkage, Inches.				Temperature.	
	A	B	C	D	A & B	C & D
Ingot.	Rail.	Rail.	Rail.	Rail.	Rails.	Rails.
ET6	6 3-16	6 7-16	6 2-16	6 5-16	935°C	940°C
Average		6 4-16			938°	
ET7	6 7-16	6 11-16	6 7-16	6 8-16	965°	960°
Average		6 8-16			963°	
ET8	6 12-16	6 15-16	6 10-16	6 15-16	985°	995°
Average		6 13-16			990°	
ET9	6 14-16	7 3-16	6 13-16	7 3-16	1025°	1030°
Average		7			1028°	
ET10	6 15-16	7 3-16	6 14-16	7 1-16	1020°	1025°
Average		7			1023°	

It will be noted that for the first four ingots there was a graded difference of finishing temperature and of shrinkage, but the last was

about the same as the one previous, although it had been intended to have this finished the hottest. The range in finishing temperature of the head of the rail as measured with a radiation pyrometer, between the average of the four rails of ingot ET6 and ET9 was 90°C, and the range in shrinkage was ¾ in., or from 6¼ to 7 in.

The lengths of the cold rails, their camber and whether "head sweep" or "base sweep" are shown in table 7. In sawing the rails, the two rails from each half-ingot were sawed at one time. The setting for the first pair of saws that cut the A and C rails was 33 ft. 6 11-16 in., and for the second pair that cut the B and D rails was 33 ft. 6½ in.

TABLE 7—LENGTHS AND CAMBERS OF RAILS.

Rail.	Length. Ft.	in.	Camber. in.	Concave. Head or Base Side.
ET6A	33	0 8-16	11/16	Head
B	33	0 1-16	1 15/16	"
C	33	0 9-16	3/16	"
D	33	0 3-16	2⅜	"
ET7A	33	0 4-16	⅝	Head
B	32	11 13-16	1¼	"
C	33	0 4-16	⅜	Base
D	33	0	1½	Head
ET8A	32	11 15-16	1⅞	Base
B	32	11 9-16	¼	"
C	33	0 1-16	2⅝	"
D	32	11 9-16	½	Head
ET9A	32	11 13-16	⅞	Base
B	32	11 5-16	⅞	Head
C	32	11⅞	2	Base
D	32	11 5-16	1⅛	Head
ET10A	32	11 12-16	1⅜	Base
B	32	11 5-16	⅞	Head
C	32	11 13-16	1 11/16	Base
D	32	11 7-16	1⅛	Head

Rail ET6D was classified on inspection as a No. 2 rail, due to roughness at the under corner of the head at two or three places near the middle of its length, and rail ET7D was also so classified on account of a flaw in the web near the middle of its length.

The various discards from the blooms and the rail bars and the weights of the ingots are shown in table 8.

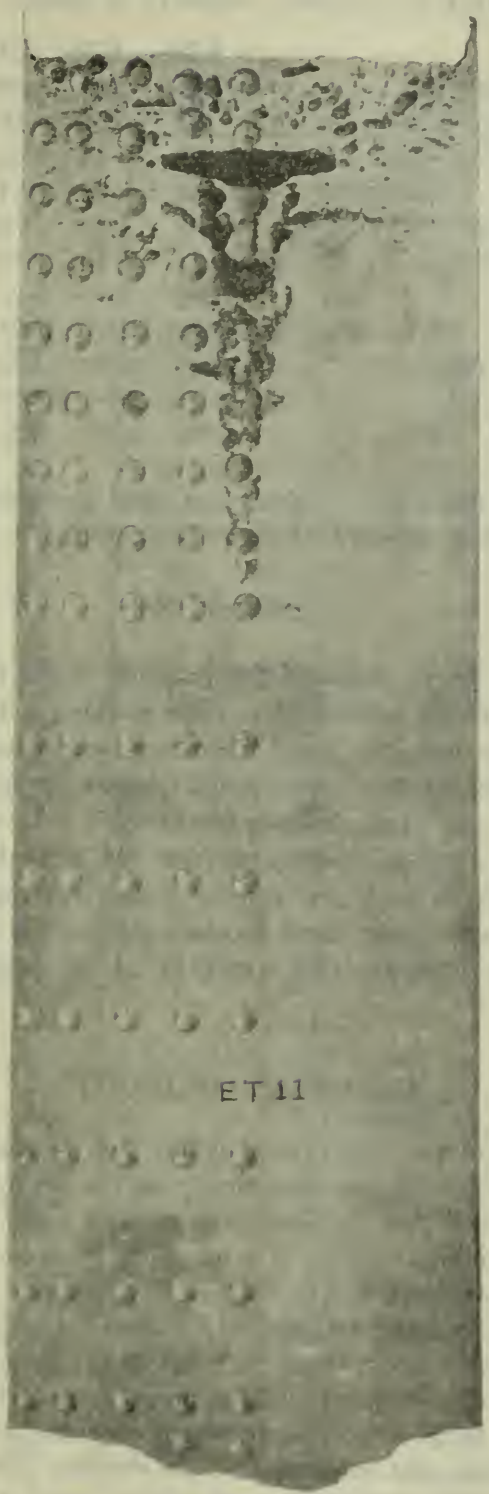


FIG. 1—LONGITUDINAL SECTION OF INGOT ET 11 ABOUT ¾ IN. FROM AXIS DRILLED FOR ANALYSIS.

TABLE 8—DISCARDS—WEIGHTS OF INGOTS.

	ET6	ET7	ET8	ET9	ET10
Discard from bloom, top	235	270	220	278	334
Discard from bloom, bottom	185	108	185	260	204
Discard from rail bar, top	21	54	57	67	63
First intermediate	46	43	47	53	59
Second intermediate	43	52	59	86	70
Bottom	34	49	45	49	52
Total discard	564	576	613	793	782
Weight of four rails	3,740	3,740	3,740	3,740	3,740
Total weight of ingot	4,304	4,316	4,353	4,533	4,522

The weight of ingot ET11, which was used for splitting and chemical survey, was 4,580 lbs., weighed whole after cooling.

INGOT.

As stated the fourth ingot of the pouring, given test number ET11, was set aside for direct examination after soaking 2 hrs. 24 min. This ingot was split across the small diameter and planed to a smooth surface. Fig. 1 shows this longitudinal section about ¾ in. from the axis of the ingot and after drilling for analysis. It will be noted that the central cavity extends downward from the top about one-third the length of the ingot, with a few smaller holes still lower. The general sponginess at the top of the ingot extends downward about 15 per cent. This ingot was 51 in. high, 18¼ x 19¼ in. at the bottom and 17 x 18¼ in. at the top.

ANALYSES OF INGOT.

This section of the ingot was drilled for a chemical survey, the samples for analysis being taken as shown on the drilling diagram, Fig. 2. It will be noted that we obtained five vertical rows of drillings from one-half of the section, making a total of 75 samples, less the number that could not be obtained, due to cavities in the ingot. The thick half of the ingot was used and the drilling cut through the axial plane. In addition, two samples were taken from the bulge at the bottom of the ingot and called samples 100D and 100E. The ingot after drilling is shown in Fig. 1. On each sample determinations were made of carbon (by combustion), phosphorus and sulphur, and on samples 99A, B, C, D and E, and 100D and E, the manganese and silicon were also determined as representing the average in the ingot. The results on carbon, phosphorus and sulphur are shown in tables 9, 10 and 11, respectively. The manganese and silicon are shown in table 12.

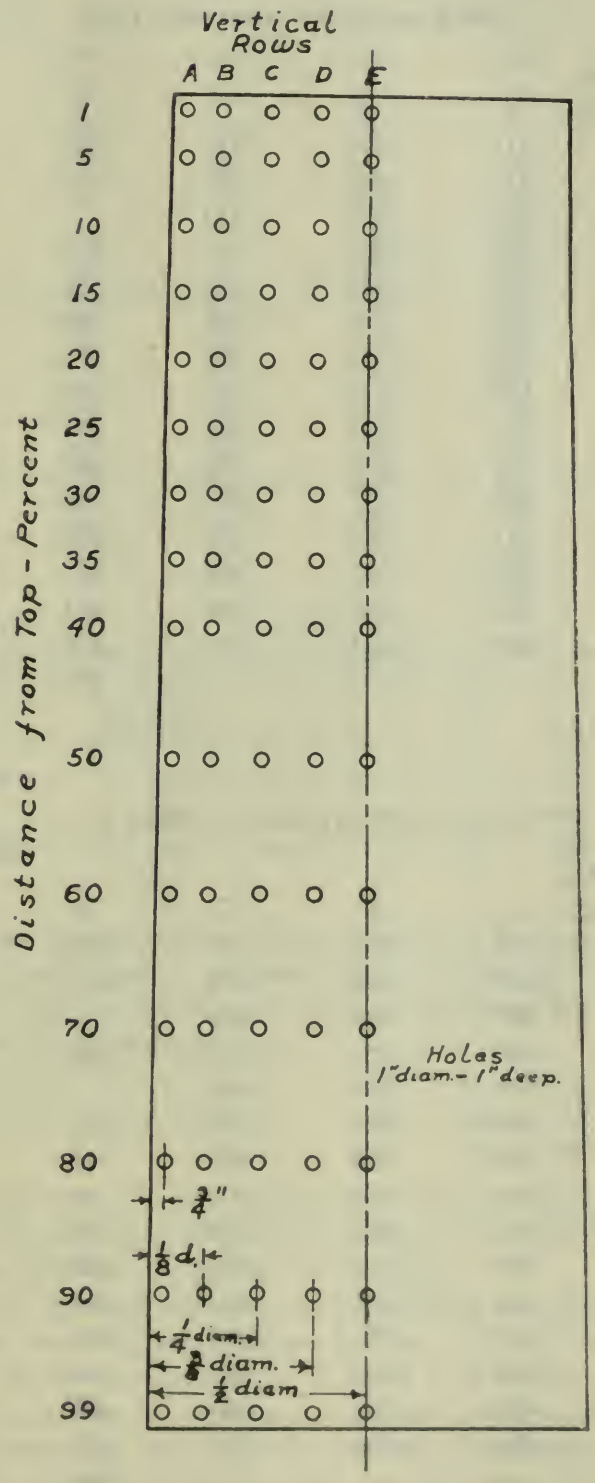


FIG. 2—DRILLING DIAGRAM FOR INGOT.

TABLE 9—CARBON IN INGOT ET11.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.415	.470	.435	.453	.419
5	.473	.455	.482	.472	.493
10	.525	.510	.532	...	...
15	.514	.395	.542	.834	...
20	.531	.523	.554	.624	...
25	.530	.519	.528	.599	...
30	.515	.523	.568	.482	.662
35	.518	.515	.535	.523	.530
40	.540	.483	.529	.464	.519
50	.514	.501	.464	.502	.446
60	.489	.435	.486	.426	.459
70	.513	.524	.482	.480	.452
80	.503	.497	.492	.457	.411
90	.515	.445	.497	.454	.468
99	.492	.471	.491	.489	.483
100	...	...	...	.482	.494

TABLE 10—PHOSPHORUS IN INGOT ET11.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.068	.064	.055	.070	.062
5	.077	.080	.075	.074	.080
10	.085	.075	.082	...	...
15	.086	.082	.075	.184	...
20	.091	.080	.092	.115	...
25	.090	.090	.088	.117	...
30	.092	.090	.098	.098	.095
35	.092	.083	.103	.105	.096
40	.091	.095	.089	.075	.098
50	.082	.091	.077	.086	.100
60	.095	.094	.099	.080	.080
70	.100	.081	.090	.105	.084
80	.076	.097	.093	.092	.088
90	.092	.095	.090	.088	.086
99	.089	.094	.095	.092	.096
100	...	...	...	.095	.094

TABLE 11—SULPHUR IN INGOT ET11.

Per Cent. from Top.	A.	B.	C.	D.	E.
1	.058	.061	.049	.048	.054
5	.069	.060	.067	.048	.061
10	.058	.059	.047	...	...
15	.069	.061	.057	.136	...
20	.071	.074	.074	.118	...
25	.070	.074	.065	.099	...
30	.083	.073	.085	.093	.104
35	.075	.083	.074	.081	.092
40	.077	.074	.079	.082	.075
50	.079	.069	.073	.067	.086
60	.071	.074	.068	.069	.065
70	.078	.075	.070	.072	.075
80	.076	.078	.067	.066	.070
90	.074	.074	.069	.063	.067
99	.079	.076	.077	.069	.073
100	...	...	...	.084	.073

TABLE 12—MANGANESE AND SILICON IN INGOT ET11.

	Per Cent. from Top.	A.	B.	C.	D.	E.
Manganese	... 99	1.04	.98	1.15	1.12	1.15
"	... 100	...	..	...	1.04	1.08
Silicon.....	99	.19	.17	.17	.18	.19
"	 100	...	..	...	.18	.18

Probably the seven samples at the bottom of the ingot, 99 A, B, C, D and E and 100 D and E, represent fairly closely the average steel in the ingot and I give below their average composition, and, for comparison, the results on the heat sample:

	C.	P.	S.	Mn.	Si.
Average of seven bottom samples.....	.486	.093	.076	1.08	.18
Heat sample.....	.487	.095	.067	1.10	.19

It will be noticed that the two results agree closely except as to sulphur, where there is a difference of .009 per cent, more as shown by the average of the samples from the bottom of the ingot.

At any given distance from the top of the ingot the extreme variations in composition are, in general, shown by the axis and the walls of the ingot, and, to show conveniently the changes from the top to the bottom of the ingot, I give Fig. 3, showing the plotted results for carbon, phosphorus and sulphur for the axis and the wall of the ingot, showing the amount of the element vertically and the per cent. from the top of the ingot horizontally. Where samples could not be obtained from the axis on account of cavities, the results from row D were taken as repre-

senting the axis. Lines are also shown representing the average carbon, phosporus and sulphur in the ingot. It will be noticed that the axis at the top shows negative segregation of the three elements, but the amounts increase rapidly and show considerable positive segregation, reaching

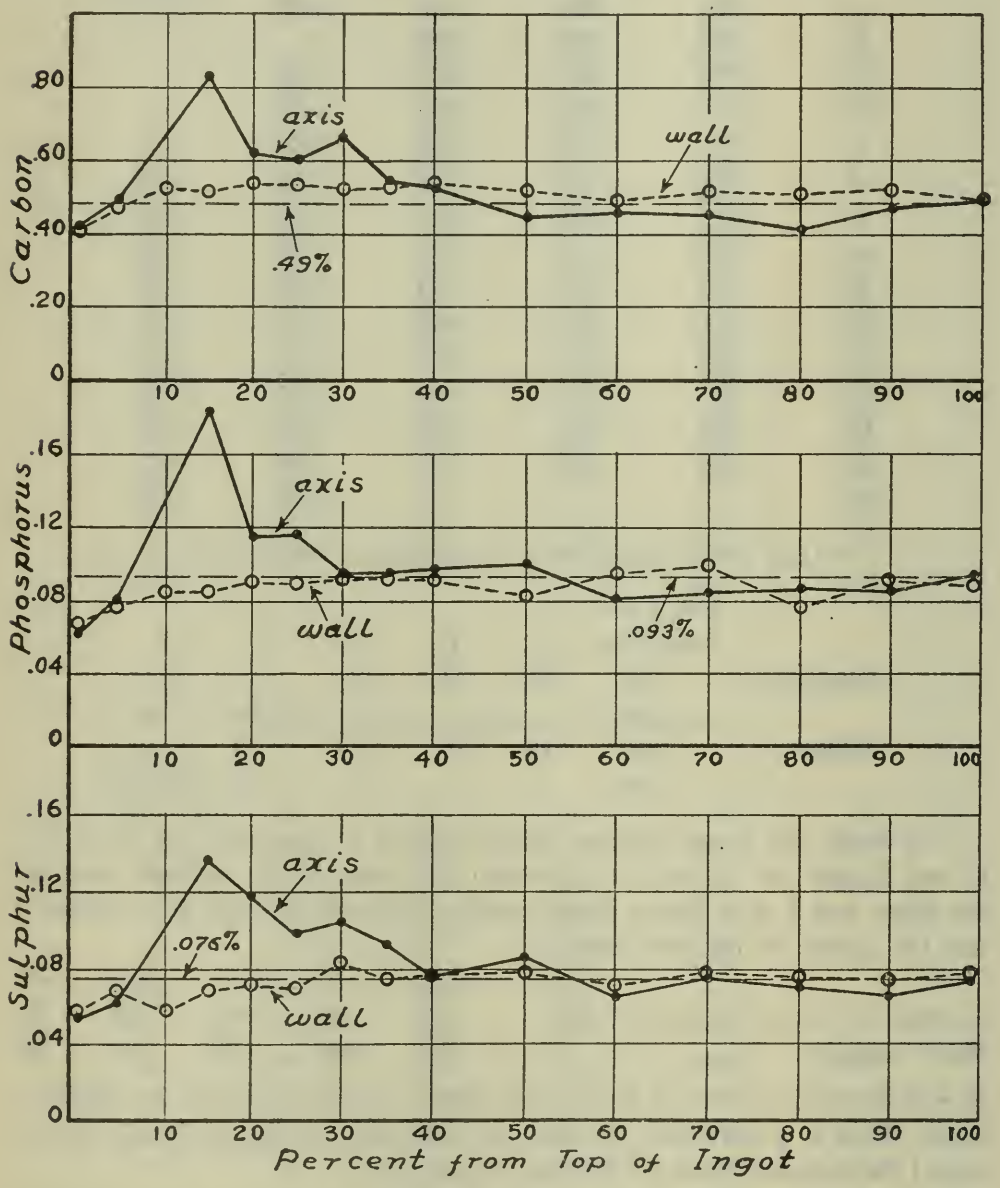


FIG. 3—CARBON, PHOSPHORUS AND SULPHUR IN THE AXIS AND WALL OF INGOT ET11.

a maximum at about 15 per cent. by distance from the top of the ingot. At about halfway down, the elements again reach the average amount in the ingot and continue to decrease, showing some negative segregation in the lower half of the ingot. The amounts again rise close to the bottom and reach the average content of the ingot.

The wall of the ingot also shows negative segregation of the three elements at the top, but the amounts gradually rise until the average amount is reached, about 15 to 20 per cent, by distance from the top, after which it remains roughly uniform.

The maximum positive segregation found at the axis and the maximum negative segregation found in the wall are shown in table 13.

TABLE 13—POSITIVE AND NEGATIVE SEGREGATION.

	Carbon.	Phosphorus.	Sulphur.
Maximum at axis.....	.834	.184	.136
Increase	72%	98%	79%
Minimum in wall.....	.415	.068	.058
Decrease	16%	27%	31%

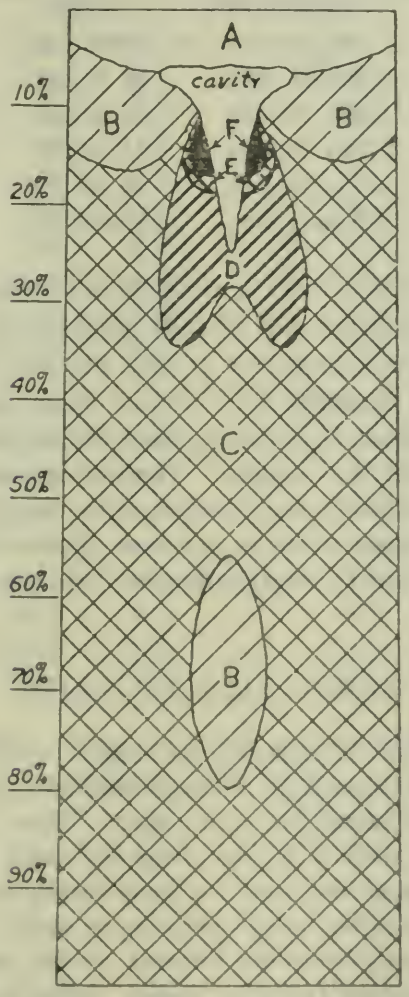


FIG. 4—DISTRIBUTION OF PHOSPHORUS IN INGOT ET11. A, BELOW .070; B, .070 TO .085; C, .085 TO .105; D, .105 TO .135; E, .135 TO .175; F, ABOVE .175

It was considered unnecessary for the purposes of this investigation to determine the manganese and silicon on all the samples, as other work has shown that manganese segregates to a much smaller extent than the carbon, phosphorus or sulphur, and silicon shows no noticeable segregation.

Fig. 4 is given to show the separation of the phosphorus into regions of different concentrations, and the same diagram can be taken to represent the distribution of the carbon and sulphur. Six concentrations of phosphorus were selected, as shown in table 14, and the approximate amounts of carbon and sulphur represented by these regions are also shown in the same table.

TABLE 14—REGIONS OF VARIOUS CONCENTRATIONS.

	Phosphorus.	Carbon.	Sulphur
A	Below .070	Below .45	Below .060
B	.070 to .085	.45 to .48	.060 to .068
C	.085 to .105	.48 to .53	.068 to .080
D	.105 to .135	.53 to .60	.080 to .100
E	.135 to .175	.60 to .70	.100 to .125
F	Above .175	Above .70	Above .125

It should be stated that there is considerable irregularity in the results and the various regions are not sharply defined as shown on the diagram, although they are correct in a very general way. The region of greatest concentration is shown by F in the upper part of the ingot surrounding the "pipe," about 15 per cent. from the top by distance, and probably about 10 per cent. by weight. The top 5 per cent. of the ingot shows considerable negative segregation, with a region of milder negative segregation for about 10 or 15 per cent. below this, and there is also a region of some negative segregation in the interior and lower part of the ingot.

TESTS MADE OF RAILS.

The entire rail-bar of each of the ingots used for rails was used for drop tests, tensile tests and microphotographs, and was divided into units of one-third rail length, or 11 ft., each. From each 11 ft., 1 ft. was cut for tensile tests, then 5 ft. for drop test with the head in tension, and the other 5-ft. piece was used for drop test with the base in tension. From each 1-ft. piece three tensile tests were made, one from the upper corner of the head, one from the interior of the head near its junction with the web, and the third from the flange. Microscopic tests were made of the three tensile test pieces from the top end of the rail. From each rail, then, nine tensile tests and three microscopic tests were made. In all, nine pieces were cut from each rail, as shown in table 15.

TABLE 15—TESTS FROM EACH RAIL.

No. 1—1 ft. Tensile and microscopic tests.
2—5 ft. Drop test, head tension.
3—5 ft. Drop test, base tension.
4—1 ft. Tensile tests.
5—5 ft. Drop test, head tension.
6—5 ft. Drop test, base tension.
7—1 ft. Tensile tests.
8—5 ft. Drop test, head tension.
9—5 ft. Drop test, base tension.

The distance of each piece from the top of the ingot, expressed in lbs. and in per cent., is shown in tables 16 to 20, inclusive. This distance is figured to the middle of the test piece.

TABLE 16—TEST PIECES OF INGOT ET6—DISTANCE FROM TOP.

Test.	Lbs.	Per Cent.	Test.	Lbs.	Per Cent.
ET6A1	270	6.3	ET6B1	1,205	28.0
A2	355	8.3	B2	1,290	30.0
A3	497	11.5	B3	1,432	33.3
A4	582	13.5	B4	1,517	35.2
A5	667	15.5	B5	1,602	37.2
A6	809	18.8	B6	1,744	40.6
A7	894	20.8	B7	1,829	42.5
A8	979	22.8	B8	1,914	44.5
A9	1,121	26.0	B9	2,056	47.8
ET6C1	2,229	51.8	ET6D1	3,164	73.6
C2	2,314	53.8	D2	3,249	75.5
C3	2,456	57.0	D3	3,391	78.8
C4	2,541	59.1	D4	3,476	80.8
C5	2,626	61.1	D5	3,561	82.8
C6	2,768	64.4	D6	3,703	86.1
C7	2,853	66.3	D7	3,788	88.1
C8	2,938	68.3	D8	3,873	90.0
C9	3,080	71.6	D9	4,015	93.3

TABLE 17—TEST PIECES OF INGOT ET7—DISTANCE FROM TOP.

Test.	Lbs.	Per Cent.	Test.	Lbs.	Per Cent.
ET7A1	338	7.8	ET7B1	1,273	29.5
A2	423	9.8	B2	1,358	31.5
A3	565	13.1	B3	1,500	34.8
A4	650	15.1	B4	1,585	36.8
A5	735	17.1	B5	1,670	38.7
A6	877	20.3	B6	1,812	42.0
A7	962	22.3	B7	1,897	44.0
A8	1,047	24.3	B8	1,982	46.0
A9	1,189	27.6	B9	2,124	49.3

ET7C1	2,303	53.3	ET7D1	3,238	75.0
C2	2,389	55.3	D2	3,323	77.0
C3	2,530	58.6	D3	3,465	80.3
C4	2,615	60.6	D4	3,550	82.3
C5	2,700	62.6	D5	3,635	84.3
C6	2,842	65.9	D6	3,777	87.5
C7	2,927	67.9	D7	3,862	89.5
C8	3,012	69.8	D8	3,947	91.5
C9	3,154	73.1	D9	4,089	94.8

TABLE 18—TEST PIECES OF INGOT ET8—DISTANCE FROM TOP.

Test.	Lbs.	Per Cent.	Test.	Lbs.	Per Cent.
ET8A1	291	6.7	ET8B1	1,226	28.2
A2	376	8.7	B2	1,311	30.1
A3	518	11.9	B3	1,453	33.4
A4	603	13.9	B4	1,538	35.3
A5	688	15.8	B5	1,623	37.3
A6	830	19.1	B6	1,765	40.5
A7	915	21.0	B7	1,850	42.5
A8	1,000	23.0	B8	1,935	44.5
A9	1,142	26.2	B9	2,077	47.7

ET8C1	2,267	52.1	ET8D1	3,202	73.5
C2	2,352	54.0	D2	3,287	75.6
C3	2,494	57.3	D3	3,429	78.8
C4	2,579	59.3	D4	3,514	80.7
C5	2,664	61.2	D5	3,599	82.7
C6	2,806	64.3	D6	3,741	86.0
C7	2,891	66.5	D7	3,826	88.0
C8	2,976	68.4	D8	3,911	90.0
C9	3,118	71.6	D9	4,053	93.2

TABLE 19—TEST PIECES OF INGOT ET9—DISTANCE FROM TOP.

Test.	Lbs.	Per Cent.	Test.	Lbs.	Per Cent.
ET9A1	359	7.9	ET9B1	1,294	28.6
A2	444	9.8	B2	1,379	30.5
A3	586	12.9	B3	1,521	33.6
A4	671	14.8	B4	1,606	35.5
A5	756	16.7	B5	1,691	37.4
A6	898	19.8	B6	1,833	40.5
A7	983	21.7	B7	1,918	42.4
A8	1,068	23.6	B8	2,003	44.3
A9	1,210	26.8	B9	2,145	47.4

ET9C1	2,368	52.3	ET9D1	3,303	73.0
C2	2,453	54.2	D2	3,388	74.9
C3	2,595	57.3	D3	3,530	78.0
C4	2,680	59.2	D4	3,615	79.9
C5	2,765	61.1	D5	3,700	81.8
C6	2,907	64.3	D6	3,842	85.0
C7	2,992	66.1	D7	3,927	86.8
C8	3,077	68.0	D8	4,012	88.6
C9	3,219	71.2	D9	4,154	91.8

TABLE 20—TEST PIECES OF INGOT ET10—DISTANCE FROM TOP.

Test.	Lbs.	Per Cent.	Test.	Lbs.	Per Cent.
ET10A1	411	9.1	ET10B1	1,346	29.8
A2	496	11.0	B2	1,431	31.7
A3	638	14.1	B3	1,573	34.8
A4	723	16.0	B4	1,658	36.7
A5	808	17.9	B5	1,743	38.6
A6	950	21.0	B6	1,885	41.7
A7	1,035	22.9	B7	1,970	43.6
A8	1,120	24.8	B8	2,055	45.5
A9	1,262	27.9	B9	2,197	48.6
ET10C1	2,410	53.3	ET10D1	3,345	74.1
C2	2,495	55.2	D2	3,430	76.0
C3	2,637	58.3	D3	3,572	79.1
C4	2,722	60.2	D4	3,657	81.0
C5	2,807	62.1	D5	3,742	82.9
C6	2,949	65.3	D6	3,884	86.0
C7	3,034	67.2	D7	3,969	87.9
C8	3,119	69.1	D8	4,054	89.8
C9	3,261	72.2	D9	4,196	92.9

DROP TESTS.

Six drop tests were made of each rail, three with the head in tension and three with the base in tension. The tup was 2,000 lbs., the height of drop was 18 ft., the supports were 3 ft. apart, and the anvil was the standard spring supported anvil of 20,000 lbs. The deflection or set was taken as the distance between a 3-ft. straight edge and the part of the rail where struck by the tup. Gage marks 1 inch apart were put on the side in tension for a distance of 6 inches, and the length of the space which stretched most at failure was determined and taken as a measure of the ductility of the rail. The results of the drop tests are shown in table 21 to 25, inclusive, showing the test number, the distance from the top of the ingot in per cent. of the weight, whether head or base in tension, the set after the first blow, the number of blows that it took to break the rail and the per cent. of stretch of the inch that stretched most at failure. The averages of each test piece location of the various rail-bars are shown in table 26.

TABLE 21—DROP TESTS, INGOT ET6, AVERAGE SHRINKAGE, 6 4-16 IN.

Test Number.	Per Cent. From Top of Ingot.	Head or Base in Tension.	Set 1st Blow.	No. of Blows.	Maximum Elongation Per Cent.	Remarks.
ET6A2	8.3	Head	1.80	2	10	
A3	11.5	Base	1.69	2	14	
A5	15.5	Head	1.65	2	11	
A6	18.8	Base	1.67	4	23	
A8	22.8	Head	1.68	3	19	
A9	26.0	Base	1.66	4	20	
ET6B2	30.0	Head	1.60	4	18	Not broken.
B3	33.3	Base	1.72	4	20	
B5	37.2	Head	1.68	4	20	
B6	40.6	Base	1.67	4	18	
B8	44.5	Head	1.71	3	21	
B9	47.8	Base	1.67	4	18	
ET6C2	53.8	Head	1.78	3	21	
C3	57.0	Base	1.72	2	6	Broke about 5 in. from support.
C5	61.1	Head	1.87	3	22	
C6	64.4	Base	1.78	4	19	
C8	68.3	Head	1.80	4	19	
C9	71.6	Base	1.80	3	12	Broke at support.
ET6D2	75.5	Head	1.76	4	30	
D3	78.8	Base	1.72	5	32	Not broken.
D5	82.8	Head	(2.02)	2	12	Not broken through head.
D6	86.1	Base	1.80	5	20	
D8	90.0	Head	1.78	3	26	Broke near support.
D9	93.3	Base	1.80	5	24	
Average.....			1.731	3.5	19.0	

TABLE 22—DROP TESTS, INGOT ET7, AVERAGE SHRINKAGE, 6 8-16 IN.

Test Number.	Per Cent. From Top of Ingot.	Head or Base in Tension.	Set 1st Blow.	No. of Blows.	Maximum Elongation Per Cent.	Remarks.
ET7A2	9.8	Head	Broke	1	6	
A3	13.1	Base	1.70	3	14	
A5	17.1	Head	1.63	3	18	
A6	20.3	Base	1.68	3	13	
A8	24.3	Head	1.65	2	10	
A9	27.6	Base	1.68	4	20	

ET7B2	31.5	Head	1.74	2	10	
B3	34.8	Base	1.65	5	24	
B5	38.7	Head	1.76	2	10	
B6	42.0	Base	1.73	4	17	Broke near support.
B8	46.0	Head	1.66	2	14	
B9	49.3	Base	1.71	5	20	
ET7C2	55.3	Head	1.77	4	23	
C3	58.6	Base	1.73	3	18	
C5	62.6	Head	1.70	5	20	
C6	65.9	Base	1.72	5	20	
C8	69.8	Head	1.76	4	26	
C9	73.1	Base	1.78	3	16	
ET7D2	77.0	Head	1.80	5	33	Not broken in head.
D3	80.3	Base	1.81	4	22	Broke near support.
D5	84.3	Head	1.77	5	27	
D6	87.5	Base	1.78	5	22	
D8	91.5	Head	1.77	4	24	
D9	94.8	Base	1.70	4	22	
Average.....			1.728	3.6	18.7	

TABLE 23—DROP TESTS, INGOT ET8, AVERAGE SHRINKAGE, 6 13-16 IN.

Test Number.	Per Cent. From Top of Ingot.	Head or Base in Tension.	Set 1st Blow.	No. of Blows.	Maximum Elongation Per Cent.	Remarks.
ET8A2	8.7	Head	1.81	2	10	
A3	11.9	Base	1.69	2	10	
A5	15.8	Head	1.67	2	10	
A6	19.1	Base	1.68	2	10	
A8	23.0	Head	1.69	3	16	
A9	26.2	Base	1.66	4	17	
ET8B2	30.1	Head	1.73	3	18	
B3	33.4	Base	1.65	4	18	
B5	37.3	Head	1.75	3	20	
B6	40.5	Base	1.73	3	23	
B8	44.5	Head	1.76	4	24	
B9	47.7	Base	1.74	5	22	

ET8C2	54.0	Head	1.76	3	20
C3	57.3	Base	1.70	4	20
C5	61.2	Head	1.81	3	17
C6	64.3	Base	1.72	4	20
C8	68.4	Head	1.80	3	24
C9	71.6	Base	1.70	5	18
ET8D2	75.6	Head	1.79	4	24
D3	78.8	Base	1.70	5	23
D5	82.7	Head	1.80	5	23
D6	86.0	Base	1.70	4	23
D8	90.0	Head	1.82	5	28
D9	93.2	Base	1.78	4	25
Average.....			1.735	3.6	19.3

TABLE 24—DROP TESTS, INGOT ET9, AVERAGE SHRINKAGE, 7 IN.

Test Number.	Per Cent. From Top of Ingot.	Head or Base in Tension.	Set 1st Blow.	No. of Blows.	Maximum Elongation Per Cent.	Remarks.
ET9A2	9.8	Head	Broke	1	4	
A3	12.9	Base	1.63	2	8	
A5	16.7	Head	1.78	2	10	
A6	19.8	Base	1.71	5	22	
A8	23.6	Head	1.76	2	17	
A9	26.8	Base	1.72	4	20	
ET9B2	30.5	Head	1.73	4	23	
B3	33.6	Base	1.65	4	18	
B5	37.4	Head	1.72	4	21	
B6	40.5	Base	1.75	5	18	
B8	44.3	Head	1.71	4	24	
B9	47.4	Base	1.75	3	18	
ET9C2	54.2	Head	1.80	4	22	
C3	57.3	Base	1.70	5	20	
C5	61.1	Head	1.82	4	22	
C6	64.3	Base	1.71	4	22	
C8	68.0	Head	1.77	4	24	
C9	71.2	Base	1.73	5	24	
ET9D2	74.9	Head	1.92	5	31	Broke at support.
D3	78.0	Base	1.84	5	24	Not broken.
D5	81.8	Head	1.85	5	29	
D6	85.0	Base	1.85	4	26	
D8	88.6	Head	1.86	4	34	
D9	91.8	Base	1.86	4	25	
Average.....			1.709	3.9	21.1	

TABLE 25—DROP TESTS, INGOT ETIO, AVERAGE SHRINKAGE, 7 IN.

Test Number.	Per Cent. From Top of Ingot.	Head or Base in Tension.	Set 1st Blow.	No. of Blows.	Maximum Elongation Per Cent.	Remarks.
ET10A2	11.0	Head	Broke	1	5	
A3	14.1	Base	1.70	2	11	
A5	17.9	Head	1.75	2	10	
A6	21.0	Base	1.67	3	14	
A8	24.8	Head	1.71	2	9	
A9	27.9	Base	1.78	3	16	
ET10B2	31.7	Head	1.80	4	19	
B3	34.8	Base	1.71	5	22	
B5	38.6	Head	1.72	3	18	
B6	41.7	Base	1.72	5	20	
B8	45.5	Head	1.70	4	22	
B9	48.6	Base	1.76	5	20	
ET10C2	55.2	Head	1.83	4	29	
C3	58.3	Base	1.74	3	18	
C5	62.1	Head	1.84	5	23	Not broken.
C6	65.3	Base	1.83	3	15	
C8	69.1	Head	1.83	3	22	
C9	72.2	Base	1.78	4	24	
ET10D2	76.0	Head	1.89	3	20	
D3	79.1	Base	1.81	5	27	Broke at support.
D5	82.9	Head	1.86	4	36	
D6	86.0	Base	1.86	4	26	
D8	89.8	Head	1.86	4	33	
D9	92.9	Base	1.83	4	22	
Average.....			1.784	3.5	20.0	

TABLE 26—AVERAGE RESULTS IN DROP TESTS.

Test Number.	Per Cent. From Top of Ingot.	Head or Base in Tension.	Set 1st Blow.	Number of Blows.	Maximum Elongation Per Cent.
A2	9.5	Head	1.805	1.4	7.0
A3	12.7	Base	1.682	2.2	11.4
A5	16.6	Head	1.696	2.2	11.8
A6	19.8	Base	1.682	3.4	16.4
A8	23.7	Head	1.698	2.4	14.2
A9	26.9	Base	1.700	3.8	18.6

B2	30.8	Head	1.720	3.4	17.6
B3	34.0	Base	1.676	4.4	20.4
B5	37.8	Head	1.726	3.2	17.8
B6	41.1	Base	1.720	4.2	19.2
B8	45.0	Head	1.708	3.4	21.0
B9	48.2	Base	1.726	4.4	19.6
C2	54.5	Head	1.788	3.6	23.0
C3	57.7	Base	1.718	3.4	16.4
C5	61.6	Head	1.808	4.0	20.8
C6	64.8	Base	1.752	4.0	19.2
C8	68.7	Head	1.792	3.6	23.0
C9	71.9	Base	1.758	4.0	18.8
D2	75.8	Head	1.832	4.2	27.6
D3	79.0	Base	1.776	4.8	25.6
D5	82.9	Head	1.820	4.2	25.4
D6	86.1	Base	1.798	4.4	23.4
D8	90.0	Head	1.818	4.0	29.0
D9	93.2	Base	1.794	4.2	23.6
Average			1.750	3.6	19.6

DUCTILITY IN DROP TESTS.

As stated, the inch space which stretched most at failure was taken as the measure of ductility of the piece of rail tested, and the elongation results are shown in Fig. 5. One set of diagrams represents the results with the head in tension and the other set with the base in tension, the elongation of the inch which stretched most being represented vertically and the distance from the top end of the ingot in per cent. of the total weight being represented horizontally. It will be noticed that in general the curves for the various rail-bars fall within a zone, crossing and re-crossing each other with but little, if any, relationship to the temperature at which the bars were rolled. The most prominent exceptions are with the rail-bar ET6 which had the lowest rolling temperature, and rail-bar ET7 which had the next higher rolling temperature. Considering the results with the head in tension it will be noticed that ET6 gave one low result toward the lower end of the bar, and all the results of the A and B rails of ET7, except one, showed low ductility. With the base in tension, two of the tests of the C rail of ET6 showed much lower elongation than the average and fell considerably below the zone of results.

Whether these low elongation results of the two rail-bars that were rolled at the lowest temperatures are in some way a function of the lower rolling temperature cannot be determined from these few results,

but since one rail from each of these bars had some surface flaws sufficient to classify them as "No. 2" rails, the query naturally arises whether such poor ductility results and the surface flaws which occurred in these rails may not have been due in some way to the lower rolling tem-

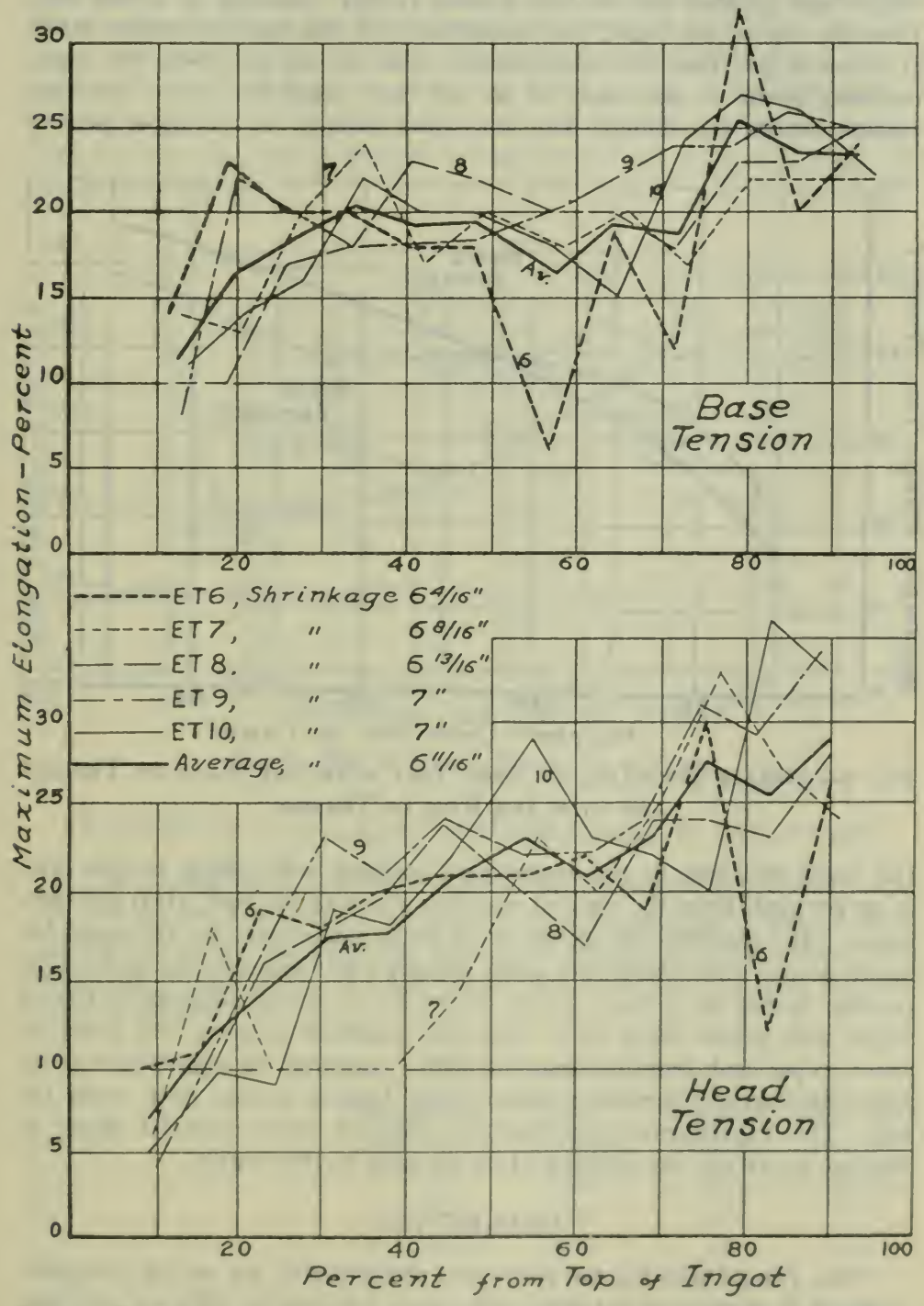


FIG. 5—DUCTILITY OF RAILS IN DROP TEST IN RELATION TO DISTANCE FROM TOP OF INGOT.

perature. Judgment on this matter must, however, be withheld until we can obtain the returns from more extended experience.

In order to show the average ductility in more convenient form, I give Fig. 6, showing one average ductility curve for the head tension results and another for the base tension results. Starting at 10 per cent. from the top of the ingot, the elongation with the head in tension starts at about 8 per cent. and continuously rises as we go down the ingot, reaching about 27 per cent. at 90 per cent. from the top. The base tension results are similar, but show more ductility in the upper part of

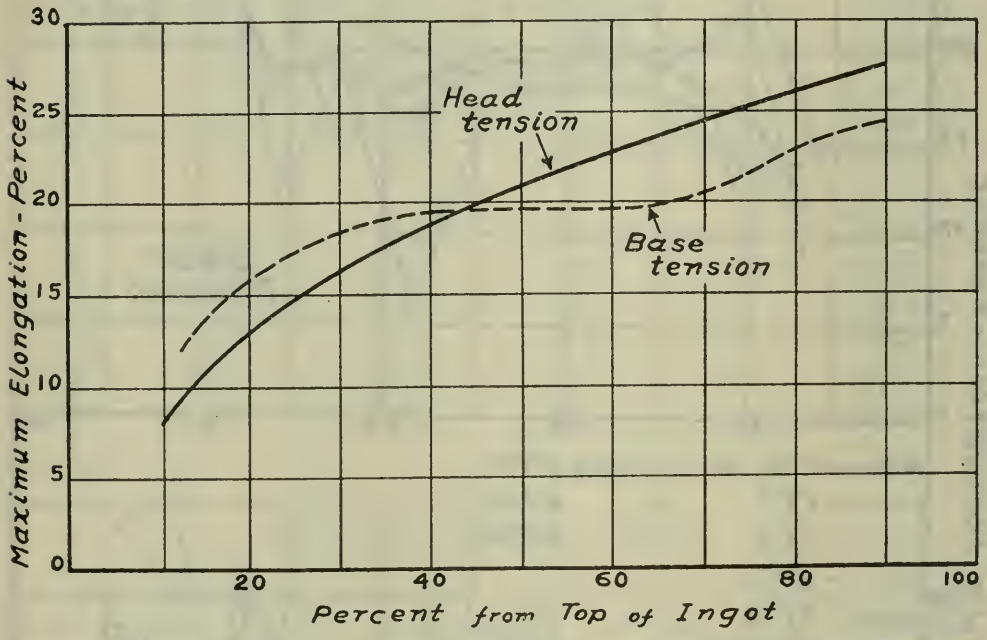


FIG. 6—AVERAGE DUCTILITY IN DROP TEST WITH THE HEAD IN TENSION AND WITH THE BASE IN TENSION.

the ingot and less in the lower part, starting with about 12 per cent. at 12 per cent. from the top and reaching about 24 per cent. at 90 per cent. down. The ductility also seems to be about stationary, for the space between 40 per cent. and 65 per cent., although this feature may perhaps be peculiar to this lot of tests. In my report No. 19 on the influence of size of ingot, with ingots about 60 in. high the minimum ductility was found at about 20 per cent. from the top, but in this case with an ingot about 51 in. high the ductility increases continuously beyond 10 per cent. from the top. The experiments, unfortunately, did not cover material closer to the top, so we can say nothing of its ductility in this region.

DEFLECTION.

The results showing the permanent deflection or set on the first blow under 18-ft. drop show but small differences between the different rail-bars. Fig. 7 shows the average deflection curves for the head tension, the base

tension and the general average results, the set on the first blow being shown vertically and the distance from the top of the ingot in per cent. of the weight being shown horizontally. This set includes the local indentation caused by the tup. It will be noted that starting at about 16 per cent. the average set is 1.69, and it increases continuously to 1.81 in. at 90 per cent. down, an average increase of about 7 per cent., although the rate of increase varies in different regions. It looks also as if the deflection is greater closer to the top also, but the data are insufficient to determine this. The set with the head in tension averages about .04 in. greater than with the base in tension.

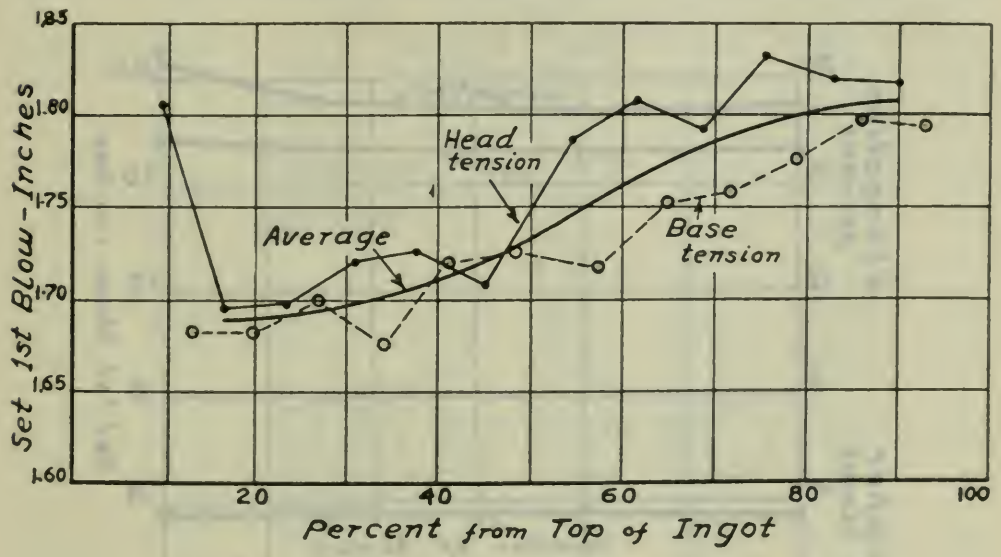


FIG. 7—SET OF RAILS UNDER 18-FT. DROP.

INFLUENCE OF ROLLING TEMPERATURE IN DROP TEST.

The average drop test results of the 24 test pieces from each rail-bar and the general averages for all the rail-bars are shown in table 27 showing the shrinkage, set after the first blow, number of blows from 18 ft. that it took to break the rail and the elongation of the inch that stretched most at failure.

TABLE 27—GENERAL AVERAGE RESULTS IN DROP TESTS.

Ingot.	Shrinkage, inches.	Set, 1st blow.	Number of blows.	Elongation, per cent.
ET6	6 4–16	1.731	3.5	19.0
ET7	6 8–16	1.728	3.6	18.7
ET8	6 13–16	1.735	3.6	19.3
ET9	7	1.769	3.6	21.1
ET10	7	1.784	3.5	20.0
Average	6 11–16	1.750	3.6	19.6

These results are shown graphically in Fig. 8, which should be studied closely in connection with the table as they summarize the important points brought out by the investigation as revealed by the drop tests. According to these results the temperature at which the rails are rolled has no very decided influence on the rails as developed by the drop test. The average set for each rail-bar is the average of 24 test pieces, 12 with the head in tension and 12 with the base in tension, but as the top piece, which was tested with head in tension, broke on three of the rail-bars on the first blow, the set could not be obtained, and for obtaining the average was assumed to be 1.81 in., the average of the two which did not break on the first blow. There seems to be a very slight increase of de-

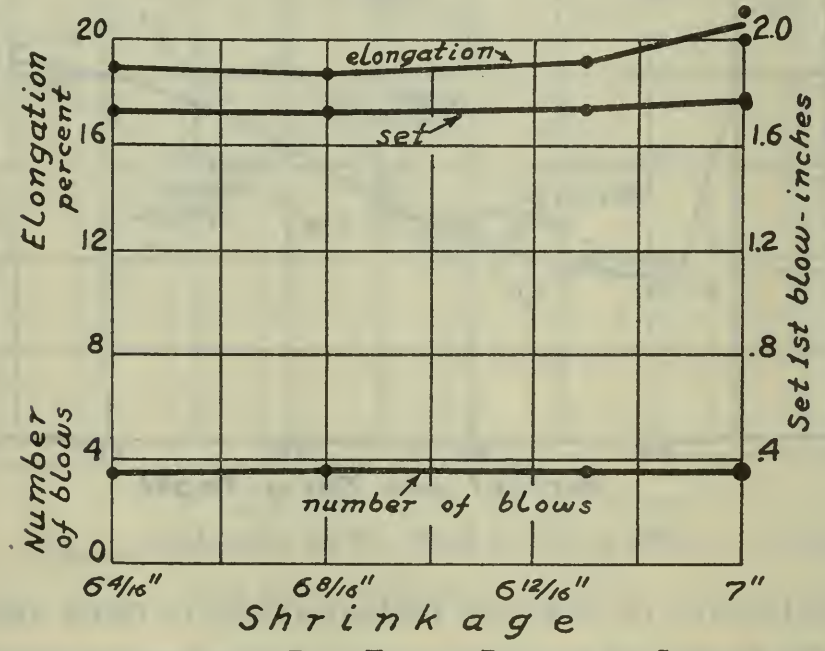


FIG. 8—RESULTS OF DROP TEST IN RELATION TO SHRINKAGE.

flection as the temperature increases, but the differences are small, ranging from about 1.73 in. to 1.78. The ductility also seems to increase a little as the temperature rises, the averages for the entire rail-bars ranging from 18.7 per cent. to 21.1 per cent. The average ductility of the bars with the lowest rolling temperatures is lowered considerably by a few very low results on those bars. The number of blows that it took to break the rails, or the accumulatied foot-lbs. of work, was just about the same for the different rail bars.

TENSILE TESTS.

Three tensile tests were made from each third of a rail length along each of the rail-bars, one sample from the upper corner of the head marked

a, one from the interior of head near the web marked b, and one from the flange marked c, as shown in Fig. 9. The samples from the corner of the head and the flange were taken from the side that was uppermost in rolling. The test pieces were 10 in. long turned to ½ in. diameter for a gage length of 2 in. and the ends were ¾ in. diameter. The tests were

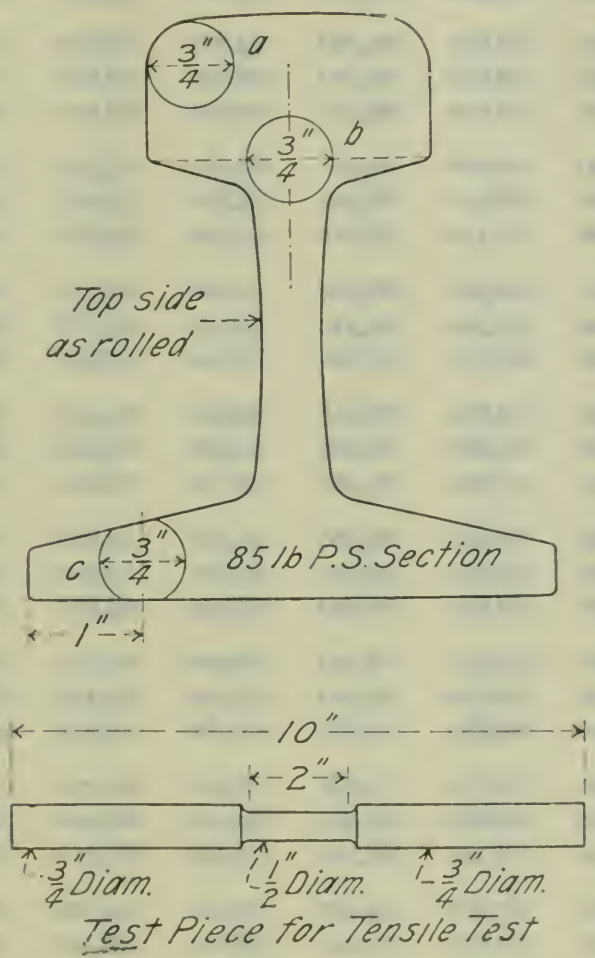


FIG. 9—TENSILE TEST—TEST PIECE AND LOCATIONS.

made in a 200,000 lb. Olson test machine and the pieces were held with wedge grips. The yield point was determined by means of a Capp's multiplying dividers. The results of the tests are shown in tables as follows:

Table 28 Yield point.
Table 29 Tensile strength.
Table 30 Elongation in 2 in.
Table 31 Reduction of area.
Table 32 Ratio of yield point to tensile strength.

TABLE 28—YIELD POINT, LBS. PFR SQ. IN.

Test Piece.	Ingot 6.	Ingot 7.	Ingot 8.	Ingot 9.	Ingot 10.	Average.	Average per cent. from top.
A1a	68,170	64,700	64,300	64,160	65,210	65,308	7.6
A1b	65,820	64,640	65,360	65,540	63,980	65,068	
A1c	64,040	66,940	64,240	66,000	64,700	65,184	
A4a	66,740	66,630	65,260	64,820	63,840	65,458	14.7
A4b	74,890	72,960	70,810	73,630	70,820	72,622	
A4c	68,040	66,740	68,265	70,020	67,300	68,073	
A7a	67,760	66,020	64,910	65,280	65,520	65,898	21.7
A7b	71,020	68,770	66,440	65,780	65,000	67,402	
A7c	69,280	68,770	78,610	67,360	67,500	70,304	
B1a	67,640	66,380	66,360	67,910	66,140	66,886	28.8
B1b	68,500	67,250	63,430	70,555	64,160	66,779	
B1c	71,420	67,740	67,760	68,470	68,130	68,704	
B4a	68,420	65,870	66,020	66,080	64,140	66,106	35.9
B4b	62,710	61,280	62,680	64,550	63,580	62,960	
B4c	66,990	77,860	66,460	68,060	66,100	69,094	
B7a	64,395	65,980	66,480	65,060	64,500	65,283	43.0
B7b	63,040	61,950	62,920	63,780	62,200	62,778	
B7c	66,990	68,830	66,940	67,140	66,700	67,320	
C1a	66,820	67,400	68,740	66,500	65,360	66,964	52.6
C1b	61,130	61,740	62,120	61,710	61,340	61,608	
C1c	68,820	68,880	67,980	67,780	77,890	70,270	
C4a	66,690	66,120	65,990	64,280	65,270	65,670	59.7
C4b	60,630	60,220	61,000	60,040	60,420	60,462	
C4c	70,450	66,740	68,740	67,020	67,350	68,060	
C7a	67,760	67,260	64,480	65,210	64,300	65,802	66.8
C7b	62,020	61,790	60,340	60,120	58,590	60,572	
C7c	69,180	67,200	67,920	68,100	67,400	67,960	
D1a	64,500	65,060	66,630	63,950	64,800	64,988	73.8
D1b	63,940	61,800	60,800	59,980	58,440	60,992	
D1c	68,370	69,815	68,640	66,450	66,160	67,887	
D4a	66,410	65,920	65,390	64,230	64,450	65,280	80.9
D4b	62,150	60,220	59,720	58,500	57,960	59,710	
D4c	66,940	67,350	65,690	65,900	65,580	66,292	
D7a	66,940	66,940	65,130	65,120	63,340	65,494	86.7
D7b	60,880	61,140	60,520	57,600	57,060	59,440	
D7c	64,960	67,240	66,140	66,240	63,900	65,696	

TABLE 29—TENSILE STRENGTH, LBS. PER SQ. IN.

Test Piece.	Ingot 6.	Ingot 7.	Ingot 8.	Ingot 9.	Ingot 10.	Average.	Average per cent. from top.
A1a	114,010	113,350	113,910	116,450	115,020	114,548	7.6
A1b	117,010	116,325	119,920	126,550	119,105	119,782	
A1c	114,480	115,025	112,530	115,680	119,200	115,383	
A4a	121,250	118,200	116,500	116,450	118,400	118,160	14.7
A4b	129,800	122,520	115,800	113,700	116,600	119,684	
A4c	117,250	120,390	118,600	119,540	120,300	119,216	
A7a	121,750	116,820	119,980	119,250	118,900	119,340	21.7
A7b	129,400	120,640	128,400	120,300	109,800	121,708	
A7c	118,200	118,500	123,500	121,660	122,100	120,792	
B1a	121,680	119,450	118,300	120,220	118,790	119,668	28.8
B1b	123,950	126,350	120,630	122,700	123,730	123,472	
B1c	118,880	122,600	121,500	125,830	121,800	122,122	
B4a	117,780	119,150	118,700	118,800	118,100	118,506	35.9
B4b	114,580	114,310	117,080	118,650	122,750	117,474	
B4c	120,020	120,810	121,070	121,150	122,500	121,110	
B7a	117,780	116,660	118,190	118,700	121,750	118,816	43.0
B7b	116,250	114,580	115,640	116,650	117,200	116,064	
B7c	121,040	118,500	120,380	120,840	121,250	120,402	
C1a	116,610	117,900	117,880	117,950	118,850	117,838	52.6
C1b	116,750	112,940	114,050	116,450	117,100	115,458	
C1c	108,000	119,100	123,010	125,170	122,900	119,636	
C4a	117,780	117,180	118,660	118,450	118,410	118,096	59.7
C4b	112,780	114,080	114,350	113,250	118,400	114,572	
C4c	119,350	120,280	123,070	122,300	122,110	121,422	
C7a	116,090	118,290	116,500	120,490	118,200	117,914	66.8
C7b	112,480	114,780	112,830	114,620	113,450	113,632	
C7c	119,290	120,830	121,560	123,740	123,050	121,694	
D1a	116,560	116,550	117,780	119,600	119,400	117,978	73.8
D1b	113,040	112,220	112,530	112,750	114,550	113,018	
D1c	117,420	118,470	120,010	121,700	122,250	119,970	
D4a	119,020	116,910	118,400	118,690	117,350	118,074	80.9
D4b	113,100	110,800	112,190	111,850	111,400	111,868	
D4c	119,160	118,250	121,090	122,000	119,450	119,990	
D7a	117,820	116,870	117,700	118,560	117,950	117,780	86.7
D7b	110,800	111,820	112,200	109,660	119,350	112,766	
D7c	115,790	117,180	117,690	120,660	117,850	117,834	

TABLE 30—ELONGATION, PER CENT. IN 2 IN.

Test Piece.	Ingot 6.	Ingot 7.	Ingot 8.	Ingot 9.	Ingot 10.	Average.	Average per cent. from top.
A1a	18.5	15	15.5	16.5	9	14.9	7.6
A1b	17.5	15	9	15	5	12.3	
A1c	18.5	15	10	16.5	14	14.8	
A4a	16.5	19	15	11	17.5	15.8	14.7
A4b	5	5.5	4	3	4	4.3	
A4c	14	17.5	12.5	10.5	15	13.9	
A7a	16	17	18	18	17.5	17.3	21.7
A7b	15	5	10.5	6	4.5	8.2	
A7c	17	16.5	17	17.5	16.5	16.9	
B1a	17	18	16	17	16	16.8	28.8
B1b	14	15	14	6	10	11.8	
B1c	16.5	18	15	16	14	15.9	
B4a	19	18.5	15.5	15.5	17.5	17.2	35.9
B4b	19	10	16	8	12	13	
B4c	18.5	18.5	16	15	17	17	
B7a	18.5	16.5	16	15	17	16.6	43.0
B7b	18	14	15.5	6	11	12.9	
B7c	18	17	15.5	16	17	16.7	
C1a	17	16.5	16	18	17.5	17.0	52.6
C1b	18	17	16.5	17.5	17.5	17.3	
C1c	17	15.5	17	16	17.5	16.6	
C4a	18.5	18.5	18.5	18	18	18.3	59.7
C4b	20	19.5	14.5	18.5	17	17.9	
C4c	17.5	18	17	16.5	16	17.0	
C7a	17	18	18.5	17	17.5	17.6	66.8
C7b	16	18	18	18	19	17.8	
C7c	16	14.5	17	17	17	16.3	
D1a	17	16.5	16.5	16.5	17.5	16.8	73.8
D1b	16.5	17	16	17	18.5	17	
D1c	16.5	17	16	17.5	17.5	16.9	
D4a	19	19	17.5	18	17.5	18.2	80.9
D4b	19	19	18.5	18	18	18.7	
D4c	19	19	17	16.5	17.5	17.8	
D7a	18.5	19	18	18	18.5	18.4	86.7
D7b	19.5	18.5	18	18.5	18.5	18.6	
D7c	19.5	19	18.5	18	18.5	18.7	

TABLE 31—REDUCTION OF AREA, PER CENT.

Test Piece.	Ingot 6.	Ingot 7.	Ingot 8.	Ingot 9.	Ingot 10.	Average.	Average per cent. from top.
A1a	30.8	15.7	21.9	23.7	7.8	19.98	7.6
A1b	28.4	21.5	23.9	20.1	4.3	19.64	
A1c	27.8	19.0	9.7	22.5	16.5	19.10	
A4a	26.7	30.8	20.8	8.2	23.3	21.96	14.7
A4b	4.0	3.2	2.3	2.4	3.2	3.02	
A4c	14.6	31.4	12.7	10.1	19.8	17.72	
A7a	25.0	25.1	29.1	27.8	25.4	26.48	21.7
A7b	9.7	5.1	10.9	6.0	3.6	7.06	
A7c	24.0	25.0	26.0	25.5	25.7	25.22	
B1a	23.7	34.4	23.3	23.6	20.5	25.10	28.8
B1b	16.4	31.4	29.0	5.2	7.5	17.90	
B1c	21.9	31.5	21.2	23.6	20.8	23.80	
B4a	35.1	30.8	22.9	19.7	28.0	27.30	35.9
B4b	34.4	9.0	21.2	7.8	10.9	16.66	
B4c	35.0	3.6	21.9	19.7	27.5	21.54	
B7a	34.1	22.9	22.6	20.8	24.7	25.02	43.0
B7b	30.5	25.7	20.8	5.2	9.8	18.04	
B7c	28.4	23.6	21.5	19.0	25.4	23.58	
C1a	27.5	24.5	21.9	31.5	27.1	26.5	52.6
C1b	30.1	26.4	23.6	24.7	26.1	26.18	
C1c	25.0	14.3	25.4	23.6	25.8	22.82	
C4a	34.1	32.1	30.8	28.5	18.7	28.84	59.7
C4b	34.7	33.1	23.3	30.8	22.6	28.90	
C4c	32.4	28.4	23.6	25.8	27.4	27.52	
C7a	24.7	31.0	30.2	24.3	28.5	25.74	66.8
C7b	19.8	29.8	26.4	25.0	28.8	25.96	
C7c	24.4	28.4	26.4	22.6	24.3	25.22	
D1a	26.7	25.4	24.0	25.8	28.2	26.02	73.8
D1b	24.3	24.7	21.9	25.7	27.1	24.74	
D1c	24.3	24.0	21.9	25.1	24.3	27.92	
D4a	29.2	32.8	29.8	28.8	25.7	29.26	80.9
D4b	27.1	30.8	25.4	26.1	27.4	27.36	
D4c	28.1	31.8	25.8	26.4	26.4	27.70	
D7a	35.4	34.7	29.5	28.5	27.4	31.10	86.7
D7b	31.4	27.8	27.1	30.5	28.0	28.96	
D7c	34.7	31.8	29.0	28.5	31.2	31.04	

TABLE 32—RATIO YIELD POINT TO TENSILE STRENGTH, PER CENT.

Test Piece.	Ingot 6.	Ingot 7.	Ingot 8.	Ingot 9.	Ingot 10.	Average.	Average per cent. from top.
A1a	59.8	57.0	56.5	55.1	56.6	57	7.6
A1b	55.3	55.6	54.5	51.7	57.9	55	
A1c	56.1	58.2	57.1	57.1	54.3	56.56	
A4a	55.1	56.3	56.7	55.6	53.9	55.52	14.7
A4b	57.8	59.6	61.2	64.8	60.7	60.82	
A4c	58.1	55.4	57.5	58.5	55.9	57.08	
A7a	55.7	56.5	54.1	54.7	56.0	55.40	21.7
A7b	55.0	57.1	51.7	54.2	59.2	55.44	
A7c	58.6	58.0	63.6	55.2	55.2	58.12	
B1a	55.6	55.6	56.1	56.4	55.6	55.86	28.8
B1b	55.2	53.2	52.6	57.6	51.8	54.08	
B1c	60.2	55.2	55.8	54.4	56.0	56.32	
B4a	58.2	53.2	55.7	55.6	54.6	55.46	35.9
B4b	54.8	53.6	53.5	54.4	51.8	53.62	
B4c	55.6	64.5	54.8	56.2	54.0	57.02	
B7a	54.7	56.6	56.2	54.9	53.0	55.08	43.0
B7b	54.3	54.1	54.4	54.8	53.1	54.14	
B7c	55.3	58.0	55.5	55.8	55.0	55.92	
C1a	57.3	57.2	58.3	56.3	54.9	56.80	52.6
C1b	52.4	54.7	54.5	53.0	52.3	53.38	
C1c	63.7	57.8	55.2	54.1	63.4	58.84	
C4a	56.7	56.3	55.6	54.2	55.1	55.58	59.7
C4b	53.8	52.8	53.3	53.0	51.0	52.78	
C4c	58.9	55.3	55 8	54.8	55.1	55.98	
C7a	58.3	56.8	55.3	54.1	54.4	55.78	66.8
C7b	55.2	53.8	53.5	52.5	51.6	53.32	
C7c	58.0	55.6	55.8	55.0	54.7	55.88	
D1a	55.3	55.7	56.6	53.5	54.2	55.06	73.8
D1b	55.6	55.0	54.0	53.2	51.0	53.76	
D1c	58.2	58.9	57.1	54.7	54.0	56.58	
D4a	55.8	56.3	55.2	54.1	54.9	55.26	80.9
D4b	54.9	54.3	53.2	52.3	52.0	53.35	
D4c	56.1	56.9	54.2	54.0	54.9	55.22	
D7a	56.8	57.2	55.4	55.0	53.7	55.62	86.7
D7b	54.9	54.7	54.4	52.7	47.8	52.90	
D7c	56.2	57.3	56.2	55.0	54.2	55.78	

The average results of the five rail-bars are shown in Fig. 10, plotted in relation to their distance from the top of the ingot, the distance from the top in per cent. being shown horizontally and the various results of yield point, tensile strength, elongation and reduction of area, being shown vertically. It will be noted that in the samples from the corner of the head and from the flange the yield point and the tensile strength are about uniform along the length of the bar, with perhaps a slight upward tendency down to about 20 per cent. from the top. The yield point and the

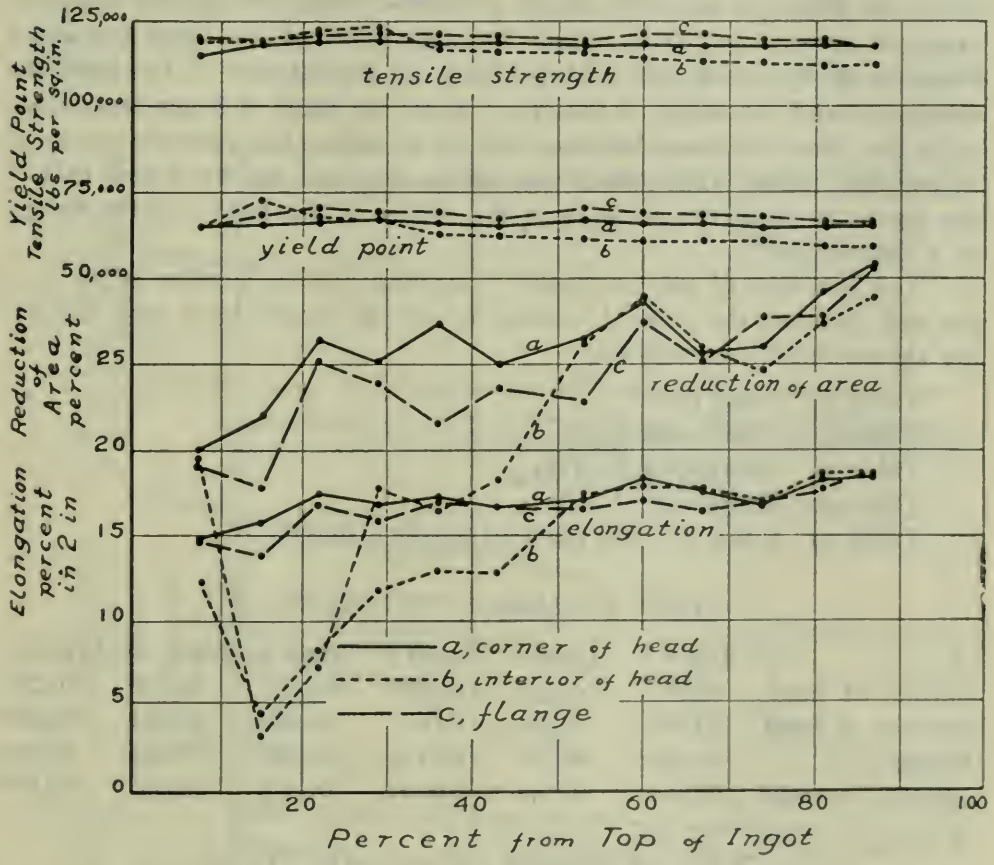


FIG. 10—AVERAGE RESULTS OF TENSILE TESTS IN RELATION TO DISTANCE FROM TOP OF INGOT.

tensile strength of the samples from the flange average about 2,000 lbs. more than those from the corner of the head, the yield point averaging about 68,000 and 66,000 lbs., respectively, and the tensile strength about 120,000 and 118,000 lbs., respectively. The samples from the interior of the head, however, do not show uniform yield point and tensile strength along the bar. These at first increase in the upper part of the ingot to above the results from the corner of the head and the flange and in the lower part of the ingot they are less, corresponding in a general way to the distribution of the hardening element, carbon and phosphorus

The elongation and reduction of area of the samples from the corner of the head and the flange increase continuously in a general way as we go down the ingot, and the samples from the corner of the head run a little higher in both properties than those from the flange. In the corner of the head the elongation runs from about 15 per cent. in 2 in. at 10 per cent. down, to about 18½ per cent. at 85 per cent. down, and in the flange it runs about one per cent. lower. The reduction of area in the corner of the head runs from about 21 per cent. at 10 per cent. down, to about 30 per cent. at 85 per cent. down, and in the flange it averages about 2 per cent. less in the upper part of the ingot but about the same in the lower part of the ingot. In the interior of the head the elongation and reduction of area start about the same at 8 per cent. down as in the other locations, but they fall off to only a few per cent. at about 15 per cent. down, after which they again rise, and for the lower half of the ingot are about the same as in the corner of the head and the flange, or a little higher.

The averages of the 12 results from each section location of each of the rail-bars and the general average of the 36 results from each rail-bar are shown in table as follows:

Table 33 Yield point.
Table 34 Tensile strength.
Table 35 Elongation in 2 in.
Table 36 Reduction of area.
Table 37 Ratio of yield point to tensile strength.

TABLE 33—AVERAGE YIELD POINTS.

	Ingot 6.	Ingot 7.	Ingot 8.	Ingot 9.	Ingot 10.	Average.
Corner of head..	66,853	66,190	65,807	65,233	64,739	65,761
Interior of head..	63,060	64,420	63,011	63,482	61,962	63,366
Flange	67,956	68,675	68,115	67,388	67,392	67,903
General average..	66,512	66,150	65,644	65,359	64,698	65,677

TABLE 34—AVERAGE TENSILE STRENGTHS.

	Ingot 6.	Ingot 7.	Ingot 8.	Ingot 9.	Ingot 10.	Average.
Corner of head..	118,177	117,277	117,708	118,634	118,427	118,059
Interior of head..	117,495	115,947	116,301	116,427	116,952	116,624
Flange	117,421	119,161	120,329	121,689	121,230	119,964
General average..	117,698	117,461	118,110	118,916	118,869	118,216

TABLE 35—AVERAGE ELONGATIONS, PER CENT. IN 2 IN.

	Ingot 6.	Ingot 7.	Ingot 8.	Ingot 9.	Ingot 10.	Average.
Corner of head..	17.70	17.62	16.75	16.54	16.75	17.07
Interior of head..	16.45	14.45	14.20	12.62	12.91	14.15
Flange	17.32	17.12	15.70	16.08	16.45	16.54
General average..	17.16	16.40	15.55	15.08	15.37	15.92

TABLE 36—AVERAGE REDUCTIONS OF AREA.

	Ingot 6.	Ingot 7.	Ingot 8.	Ingot 9.	Ingot 10.	Average.
Corner of head	29.33	28.35	25.56	25.10	23.77	26.10
Interior of head	24.23	22.37	21.31	17.45	16.60	20.36
Flange	26.71	24.40	22.09	22.70	24.59	24.43
General average	26.78	25.04	22.99	21.75	21.67	23.63

TABLE 37—AVERAGE RATIOS OF YIELD POINT TO TENSILE STRENGTH.

	Ingot 6.	Ingot 7.	Ingot 8.	Ingot 9.	Ingot 10.	Average.
Corner of head	56.44	56.22	55.97	54.95	54.74	55.70
Interior of head	54.93	54.87	54.23	54.51	53.35	54.37
Flange	57.91	57.59	56.55	55.40	55.55	56.60
General average	56.48	56.24	55.58	54.95	54.56	55.50

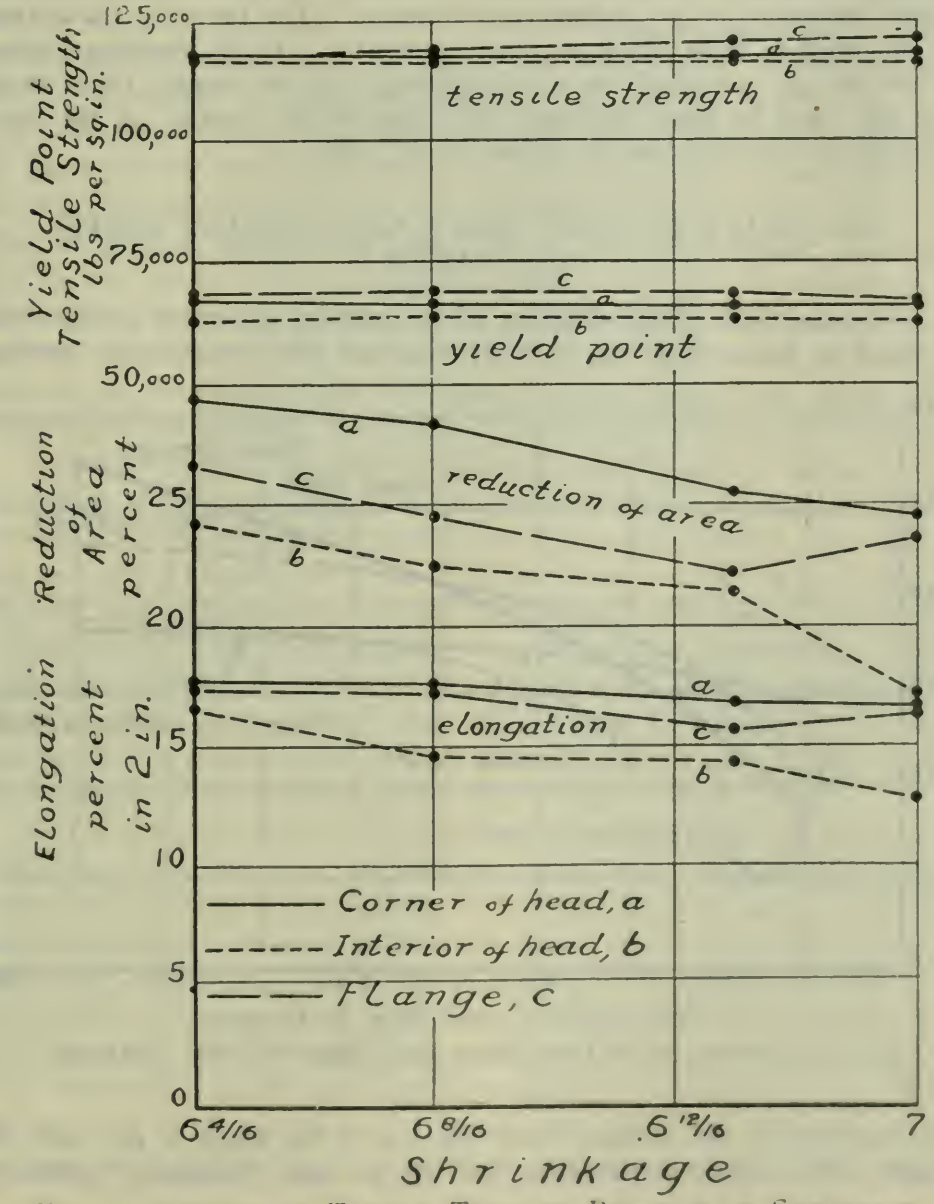


FIG. 11—RESULTS OF TENSILE TESTS IN RELATION TO SHRINKAGE.

The average results of each of the three section locations are plotted in Fig. 11 in relation to temperature of rolling, the shrinkage in a 33-ft. rail being plotted horizontally, and the yield point, tensile strength, elongation and reduction of area being plotted vertically. It will be noted that the yield point seems not to be influenced by the temperature of rolling. The tensile strength is likewise not influenced, except that the flange seems to increase a little in tensile strength as the shrinkage or temperature of rolling increases. The elongation of the corner of the head and of the flange decreases a little as the rolling temperature increases. The decrease of elongation in the interior of the head is more, ranging from about 16.5 per cent. in 2 in. at 6 4-16 in. shrinkage, to about 12.8 per cent. at 7 in. shrinkage. The influence of the rolling temperature is seen most prominently, however, in the reduction of area which decreases as the temperature increases. The range in the corner of the head is from about 29.3 per cent. at 6 4-16 in. shrinkage down to about 24½ per cent. at 7 in. shrinkage, in the flange from about 26.7 per cent. to about 23.7 per cent., and in the interior of the head from about 24.2 per cent. to about 17 per cent.

DUCTILITY IN DROP TESTS AND TENSION TESTS COMPARED.

A comparison of the ductility of the rails as measured in the drop test and in the tension test, is interesting, and Fig. 12 is given, showing

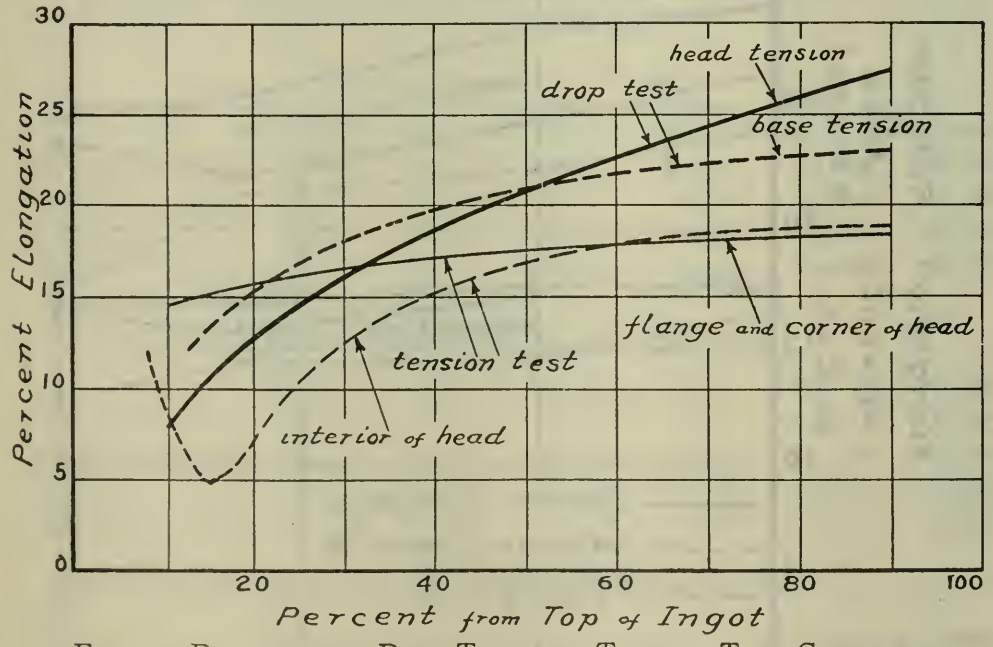


FIG. 12—DUCTILITY IN DROP TEST AND TENSION TEST COMPARED.

the comparison, the distance from the top of the ingot in per cent. of weight being plotted horizontally and the per cent. elongation vertically.

The curves of the average elongation in the head tension and in the base tension tests are reproduced as representing the ductility in the drop test. The curve showing the average elongation in tension of the samples from the interior of the head and another curve showing the average of the samples from the corner of the head and from the flange, are given as representing the ductility as measured in the tension test. In the tension test the elongation is measured on a test piece ½ in. diameter and in a gage length of 2 in., and includes the local necking down where fracture occurs. In the drop test the elongation is measured in a gage length of 1 in., this being the inch of six 1-in. spaces which stretches most at fracture. Observation of the fractures in the drop test has shown that the fracture generally starts at some point within the section and not at the outside where the greatest stretching occurs. In tests with the head in tension, with rail from the upper and segregated part of the ingot, the fracture generally starts in the interior of the head well down toward the web, but with rail from the lower part of the ingot the fracture starts nearer to the top surface, or sometimes it may start at the surface, where the material is stretched most. In tests with the base in tension the results are of a similar nature, although they do not show up as prominently because the base is thinner, and also possibly because the segregated metal is closer to the neutral axis and may not influence the result so readily. In other words, the initial point of the fracture in the drop test generally occurs, not where the greatest stretching occurs, but internally at some point of lower ductility.

In the tension test, the exterior metal as represented by the flange and the corner of the head, shows good ductility along the whole rail-bar, although there is a general increase as we go down the ingot from about 14½ per cent. elongation in 2 in. at 10 per cent. from the top, to about 18½ per cent. elongation at 90 per cent. down. The results from the interior of the head near the web, however, differ considerably from these, and while there is fair ductility near the top, the elongation drops off to less than 5 per cent. at about 15 per cent. from the top. It then rises again and in the lower part of the rail-bar averages slightly above the results from the exterior of the section.

In the drop test, with the base in tension, the elongation, as measured in this test, runs from 12 per cent. to 24 per cent. between the limits mentioned above along the rail-bar. With the head in tension there is also a continuous increase in the same part of the rail-bar, but the differences in elongation are much greater, ranging from 8 per cent. to 27 per cent. In this respect there is considerable similarity between the ductility of the interior metal as measured in the tension test of samples from the interior of the head and the ductility as measured in the drop test with the head in tension. It would seem, therefore, that this latter test may be more useful to ascertain the ductility of the interior metal

than the drop test with the base in tension, as is usual in inspection work.

MICROSTRUCTURE.

Microphotographs were made of the etched ends of the three tensile test pieces from the top end of each rail. The pieces were polished, etched with nitric acid and magnified 50 diameters in the photographs. In Figs. 13 to 27, inclusive, are reproduced the etched cross-sections from the top end of the C rail of each of the five ingots. Figs. 13 to 17, inclusive, show the cross-sections from the upper corner of the head from the "top" side, that is, the side that was uppermost in rolling, Figs. 18 to 22, inclusive, those from the interior of the head, and Figs. 23 to 27, inclusive, those from the "top" flange. These photographs show the grains of "pearlite" inclosed in the web of "ferrite," and, in general, the grains are smallest in the flange, somewhat larger in the corner of the head and largest in the interior of the head. The main purpose of the microscopic tests was to determine the influence of the rolling temperature on grain size, and table 38 is given, showing the approximate number of grains per .001 sq. in. of cross-section for each of the 60 samples examined.

TABLE 38—GRAINS PER .001 SQ. IN.

Test Piece.	Ingot 6.	Ingot 7.	Ingot 8.	Ingot 9.	Ingot 10.	Average.
A1a	120	80	50	45	50	69
B1a	100	95	75	45	35	70
C1a	100	100	50	80	90	84
D1a	80	60	60	60	50	62
Average	100	84	59	58	56	71
A1b	55	55	40	20	20	38
B1b	30	25	25	18	20	24
C1b	100	85	45	40	25	59
D1b	50	50	35	25	20	36
Average	59	54	36	26	21	39
A1c	180	140	100	85	85	118
B1c	150	100	50	45	50	79
C1c	140	100	90	50	50	86
D1c	80	70	40	40	40	54
Average	138	103	70	55	56	84
Gen. Ave.	99	80	55	46	44	65

FIG. 13—INGOT 6, SHRINKAGE 6¼ IN.

FIG. 14—INGOT 7, SHRINKAGE 6½ IN

FIG. 15—INGOT 8, SHRINKAGE 6 13-16 IN.

FIG. 16—INGOT 9, SHRINKAGE 7 IN.

FIG. 17—INGOT 10, SHRINKAGE 7 IN.

Cross Section Microphotographs from the Upper Corner of the Head of the Rail, from the "Top" Side or Side Uppermost in Rolling. Top End of C Rail. Etched with Nitric Acid and Magnified 50 Diameters.

FIG. 18—INGOT 6, SHRINKAGE 6¼ IN.

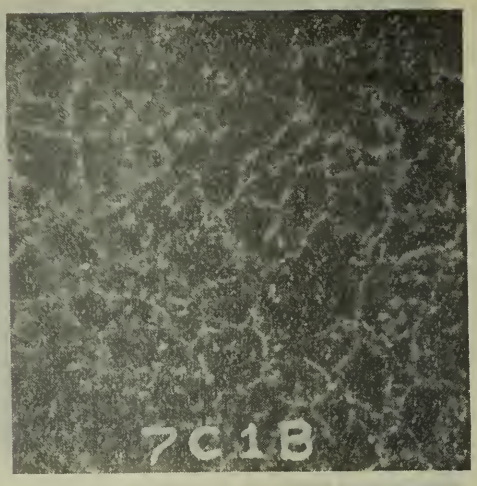


FIG 19—INGOT 7, SHRINKAGE 6½ IN.

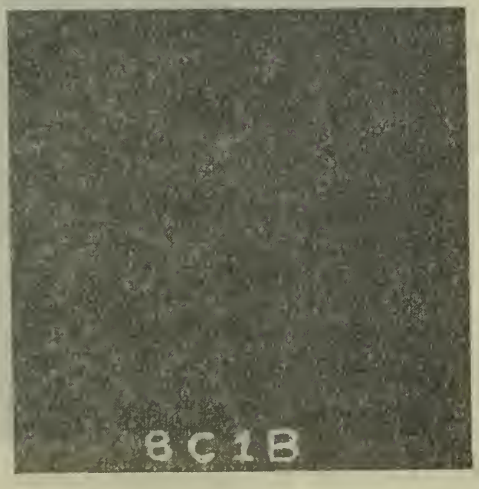


FIG. 20—INGOT 8, SHRINKAGE 6 13-16 IN.

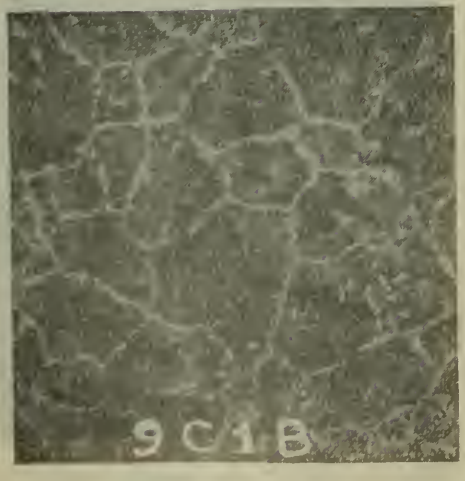


FIG. 21—INGOT 9, SHRINKAGE 7 IN.

FIG. 22—INGOT 10, SHRINKAGE 7 IN.

Cross Section Microphotographs from the Interior of the Head of the Rail near Its Junction with the Web. Top End of C Rail. Etched with Nitric Acid and Magnified 50 Diameters.

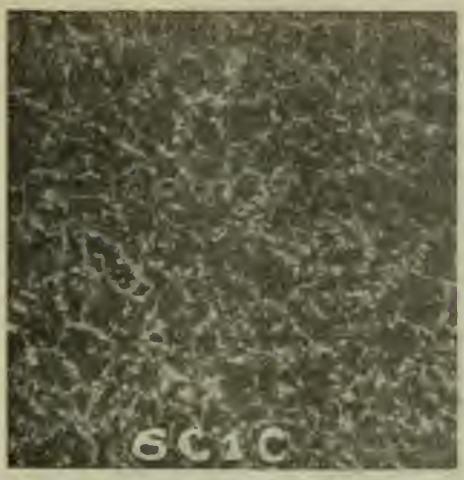


FIG. 23—INGOT 6, SHRINKAGE 6¼ IN.

FIG. 24—INGOT 7, SHRINKAGE 6½ IN.

FIG. 25—INGOT 8, SHRINKAGE 6 13-16 IN.

FIG. 26—INGOT 9, SHRINKAGE 7 IN.

FIG. 27—INGOT 10, SHRINKAGE 7 IN.

Cross Section Microphotographs from the Flange of the Rail, from the "Top" Side or Side Uppermost in Rolling. Top End of C Rail. Etched with Nitric Acid and Magnified 50 Diameters.

The average results for the four rails of each ingot are plotted in Fig. 28, the shrinkage being shown horizontally and the number of grains per .001 sq. in. vertically, for each of the three locations in the section. It will be noted that as the rolling temperature increases, the number of grains per unit of area of cross-section decreases; that is, the size of the grain increases. In the flange the number of grains per .001 sq. in. runs from 138, in ingot 6, with the lowest rolling temperature,

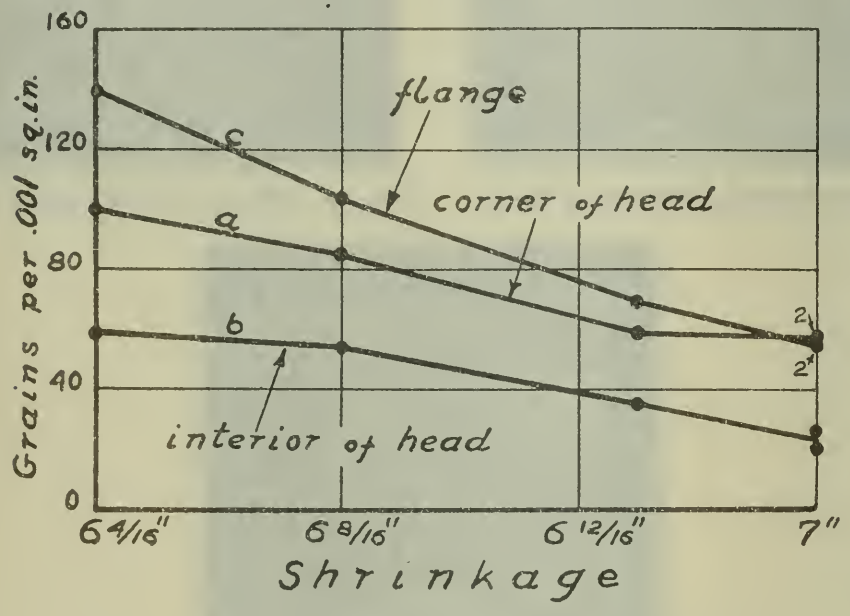


FIG. 28—SIZE OF GRAIN IN RELATION TO SHRINKAGE.

down to 55 or 56 where the temperature was hottest. In the corner of the head the range is from 100 down to 56, and in the interior of the head from 59 to 21.

SUMMARY.

1. A series of five ingots from one heat of Bessemer steel was rolled into 85 rails, all in a similar manner, except as to the temperature at which they were rolled. One ingot was rolled "cold" and the temperature was increased with the succeeding ingots, finally rolling the last ingot very hot. The ingots were about 18½ x 19½ in. at the bottom, about 51 in. high and weighed about 4,400 lbs. each. After soaking in the usual manner, the ingots were rolled into blooms about 9½ in. square and a smaller discard than usual made from the top. Each bloom was then cut in two, the two parts reheated at the same time, and were rolled into 85-lb. P. S. section rails (Pennsylvania Railroad System), four rails being made from each ingot. In addition one ingot of the same heat was used for splitting open and making a chemical survey, this ingot having been placed in the soaking pit and then cooled down. This work was all done at the works of the Carnegie Steel Com-

pany, who kindly furnished all the material and facilities for the test work.

2. The rails were examined by means of drop, tensile and microscopic tests. The comparison ingot was split open to determine the interior condition as regards cavities, and analyses were made of about 75 samples from one side of a longitudinal section near the axis to determine the distribution of the carbon, phosphorus and sulphur.

3. The shrinkage after sawing varied from 6¼ in. in a 33-ft. rail, as the average of the four rails from a whole rail-bar, to 7 in. The temperature of the head of the rail just after leaving the finishing rolls, determined by a heat radiation pyrometer, varied from 940 deg. C. to 1,030 deg. C., a range of 90 deg. C.

4. The upper 15 per cent. of the comparison ingot was spongy with blow holes generally distributed, and the central cavity extended downward about one-third way from the top.

5. The axis of the ingot showed considerable segregation of the carbon, phosphorus and sulphur, reaching a maximum at about 15 per cent by distance from the top. The maximum increases found were 72 per cent. in carbon, 98 per cent. in phosphorus and 79 per cent. in sulphur, above the average content of the ingot. The axis also showed a little negative segregation in the lower part of the ingot.

6. The walls or outer part of the section showed negative segregation at the top part of the ingot for a distance of about 15 or 20 per cent. down, after which the composition is about the average to the bottom of the ingot. The greatest decreases amounted to 16 per cent. in carbon, 27 per cent. in phosphorus and 31 per cent in sulphur below the average content of the ingot.

7. The ductility in the drop tests was determined by putting gage marks one inch apart for a distance of three inches each side of the middle longitudinally on the side in tension, and measuring the space which stretched most at failure.

8. The tests covered the rail bar from about 10 per cent. from the top down to about 90 per cent. from the top, and the remarks below refer to this part of the rail-bar. In both head tension and base tension tests the ductility, as an average of all the rail-bars, increased continuously along the rail-bar, starting from the top end. With head tension the range was from about 8 per cent. to about 27 per cent. and with base tension from about 12 per cent. to about 24 per cent.

9. The permanent deflection or set was measured under the first blow of a 2,000-lb. tup falling from a height of 18 ft., with a span of supports of 3 ft. The set measured was the distance between a 3-ft. straightedge and the part of the rail where struck by the tup.

10. As an average of the head tension and base tension results, the set at about 16 per cent by weight from the top of the ingot was 1.69 in. and increased continuously down the rail-bar until at 90 per cent down it was 1.81 in., an average increase of about 7 per cent., although the

rate of increase varied in different parts of the bar. The set with the head in tension averaged about .04 in. greater than with the base in tension. The results from the bar above 16 per cent. from the top were insufficient to allow of conclusions, but it seems that the set was greater than at 16 per cent. down.

11. Differences of rolling temperature corresponding to shrinkages of 6¼ in. to 7 in., in a 33-ft. rail, resulted in only small differences in the rails as determined by the drop test. The deflection seems to have increased slightly as the temperature increased, the averages of the bars ranging from 1.73 in. to 1.78 in. The ductility also seems to have increased some with an increase of temperature of rolling, ranging from 18.7 per cent. to 21.1 per cent. for the averages of the bars. The number of blows that it took to break the rails averaged just about the same for the different bars, namely, 3½ blows.

12. Tensile tests were made along the rail-bars from three locations in the section, the corner of the head, the interior of the head near its junction with the web, and the flange.

13. Considering the average results of the five bars, the yield point and tensile strength were about uniform along the bar in the samples from the corner of the head and the flange, with perhaps a slight upward tendency down to about 20 per cent. from the top. The flange averaged about 2,000 lbs. higher than the corner of the head both in yield point and tensile strength, the yield point averaging about 68,000 and 66,000 lbs., respectively, and the tensile strength about 120,000 and 118,000 lbs., respectively.

The yield point and tensile strength of the interior of the head at first increase to above the results from the two other locations, and in the lower part of the ingot they are less, corresponding in a general way to the distribution of the hardening elements, carbon and phosphorus.

14. The elongation and reduction of area of the corner of the head and the flange increased continuously, in a general way, downward of the ingot, the corner of the head showing a little higher in both properties than the flange. In the corner of the head the elongation averaged from 15 per cent. in 2 in. to 18½ per cent., between the limits of 10 per cent. and 85 per cent. down from the top of the ingot and in the flange the results were about 1 per cent lower. The reduction of area in the corner of the head ranged from 21 per cent. to 30 per cent. in the same region, and in the flange it averaged about 2 per cent. less in the upper part of the ingot, but about the same in the lower part.

In the interior of the head the elongation and reduction of area started at upper part of the ingot about the same as in the other locations, but they soon fell off to only a few per cent. at about 15 per cent. down, after which they increased, and in the lower half of the ingot they were about the same as in the corner of the head and the flange, or were a little higher.

15. Differences of rolling temperature corresponding to shrinkages of 6¼ in. to 7 in. in a 33-ft. rail, resulted in little or no differences in the yield point. The tensile strength was likewise not influenced, except that the flange seems to have increased a little in tensile strength as the temperature of rolling increased.

16. The elongation of the corner of the head and the flange decreased a little with increase of temperature, but the interior of the head decreased more in elongation with increase of temperature, ranging from about 16.5 per cent. in 2 in. at 6¼ in. shrinkage to about 12.8 per cent. at 7 in. shrinkage.

17. The influence of the temperature of rolling, as determined by the tensile test, is seen most prominently in the reduction of area, which decreased as the temperature increased. The range in the corner of the head was from about 29.3 per cent. at 6¼ in. shrinkage down to about 24½ per cent. at 7 in. shrinkage, in the flange from about 26.7 per cent. to about 23.7 per cent. and in the interior of the head from about 24.2 per cent. to about 17 per cent.

18. A discussion is given comparing the ductility as developed by the drop test and the tension test. In both tests the ductility increased in a general way, downward of the ingot, except that the ductility of the interior metal in the tension test was at its minimum at about 15 per cent. from the top. The exterior metal shows good ductility, as shown by the tension test, along the whole rail-bar, but the interior metal is of very low ductility at about 15 per cent. by weight from the top. This seems to show its influence in the drop test, to some extent in the tests with the base in tension, but more prominently in the tests with the head in tension.

19. Microphotographs were made of etched sections from three locations in the section; namely, the upper corner of the head, the interior of the head near its junction with the web, and the flange. As the rolling temperature increased, the number of grains per unit of area decreased, that is, the size of the grain increased. In the flange the number of grains per .001 sq. in. averaged from 138 with the lowest temperature used to 55 with the highest temperature used. In the corner of the head the range was from 100 down to 56, and in the interior of the head from 59 to 21.

20. Finally, the influence of the temperature of rolling, as ascertained by the tests made, may be summed up as follows: The ductility and deflection in the drop test were influenced little, if any, by the temperature. The number of blows that it took to break the rails in the drop test was uninfluenced by the temperature of rolling. The yield point and tensile strength in the tension tests were influenced little, if any. The elongation in the tension test decreased some as the temperature increased. The influence of temperature showed most prominently, in the tension test, in the reduction of area, which decreased as the temperature of rolling increased. The size of grain, as shown by the microscope, increased as the temperature increased.

Appendix F.

To the Members of the American Railway Engineering Association:

On January 8, 1912, the following order was issued by the Railroad Commission of Indiana:

STATE OF INDIANA.

RAILROAD COMMISSION OF INDIANA.

Inquiry as to the condition of steel rails now being manufactured, purchased and put in by the railroad companies operating in the State of Indiana. } No.

WHEREAS, It is the duty of this Commission "to keep informed as to the condition of railroads and railways with reference to the security of the public," and

WHEREAS, This Commission is advised that the steel now manufactured and put in on the railways in this state is inferior to the lighter grades heretofore used, and that there is a difference of opinion between the manufacturers and carriers as to whether this steel should be still heavier to sustain the heavier equipment and loads, or should be of such better quality as were said lighter grades:

THEREFORE, Upon consideration, a formal inquiry by the Commission as to this matter is now instituted and commenced.

IT IS ORDERED, That the General Managers, General Superintendents, Engineers in charge of Maintenance of Way, and Expert Testers of new steel, and such Purchasing Agents, and such authorities on steel rail manufacture, and such roadmasters as the Commission may hereafter summon shall attend a conference on this subject at Room 83 of the State House on Tuesday, February 20, 1912, 10 a. m.

IT IS FURTHER ORDERED, That any expert on steel rail manufacture and use, who may desire to give the Commission scientific or practical information on this subject, may appear and be heard at said conference, to the end that such concerted course of action may be adopted by the Commission as will tend to secure for use on the railways of this State a high grade of steel, as perfect as to materials and manufacture and shape and weight as can be practically made. It is understood that the Commission will ask the aid and counsel of the American Railway Association, who have collected a great deal of valuable data and information on this subject.

IT IS ORDERED, That the Secretary transmit a copy of this order to each steam and interurban railroad operating in the State of Indiana.

I, J. L. Reiley, Secretary of the Railroad Commission of Indiana, hereby certify that the above and foregoing is a true and complete copy of the order issued by the Commission on the 8th day of January, 1912.

Given under my hand and seal this 8th day of January, 1912.

(Signed) J. L. REILEY,
Secretary.

Indianapolis, Indiana.

A meeting between Mr. W. J. Wood, Chairman of the Railroad Commission, and Mr. W. J. Jackson, Chairman of the Special Committee on Relation of Railway Operation to Legislation, to determine the best method for conducting the hearing, resulted in the appointment of a committee of railway men to arrange for the information on the rail question which was to be presented to the Commission. This committee was as follows: Mr. F. A. Delano, Receiver, Wabash Railroad; Mr. Fairfax Harrison, President, C. I. & L. Railway; Mr. G. L. Peck, General Manager, Pennsylvania Lines; Mr. W. C. Cushing, Chief Engineer M. of W., Pennsylvania Lines, South West System, and Dr. P. H. Dudley, Consulting Engineer, New York Central Lines.

At a conference between the members of this committee, on February 9, a sub-committee consisting of Dr. P. H. Dudley, Dr. Thos. H. Johnson and Mr. W. C. Cushing, with the latter as Chairman, was appointed to draw up statements of the work which had been done by the railway companies in the past for the improvement of rail design and specifications, to be read before the Commission as the statement of the railways.

The sub-committee divided this task up into three parts, each member taking one part, as follows:

Part I: The early history of rail development up to the time the subject was taken up by the American Society of Civil Engineers, together with the questions of relative quality of earlier and later rails, and foreign rail steel as compared with American, by Dr. P. H. Dudley.

Part II: The history of the connection of the American Society of Civil Engineers with rail design and specifications, together with the questions of lower carbon and heavier rail sections, by Dr. Thos. H. Johnson.

Part III: The question of the improvement of rail design and specifications from the American Society of Civil Engineers' report in 1893 to the present time, together with a discussion on the subject of fixed percentage of discard, by Mr. W. C. Cushing.

These papers were prepared in the very short time allotted, and read before the Commission at its hearing on February 20, and are submitted with this report.

In addition to the above, addresses were made, upon request of Chairman Wood, by Mr. F. A. Delano, Mr. E. J. Buffington, Dr. Benjamin and Mr. R. Montfort, after which the hearing was adjourned until April 2.

Respectfully submitted,

COMMITTEE IV—ON RAIL.

Part I.

THE HISTORY, DEVELOPMENT AND USE OF RAILS BY RAILROAD COMPANIES OF THE UNITED STATES FROM 1830 TO DATE.

BY P. H. DUDLEY.

The inception, projection and construction of 350,000 or more miles of track and equipment in the United States, nearly one-half of that of the world, by private enterprise, in the past eighty years, represent an expenditure of energy and capital without parallel by older nations, and express by deeds the abiding faith of the people in the growth, welfare and stability of this great country.

Our railroads were installed to furnish the most efficient means of inland transportation, to develop a new country of vast extent of territory, great diversity of topographic features and climate, yet of limited accumulation of capital, but rich in natural resources, to be converted by industry into wealth.

The opening of the Stockton & Darlington Railway in England, September 27, 1825, by George Stephenson's "Locomotion" having only a flue boiler, therefore of limited steam generating capacity, indicated that steam could replace horse power for railroad transportation, and the result was received with great interest in this country.

This was followed by a charter for the Mohawk & Hudson Railroad in 1826. Several other lines were chartered in the United States, the Baltimore & Ohio, the Delaware & Hudson Canal Company, the Camden & Amboy and the Philadelphia & Columbia Division of the Pennsylvania Railroad. The construction of the lines was commenced, and in 1830 there were 23 miles in operation. (See Table 1.)

The railroads at their inception were local affairs of few miles in extent, and without previous experience in construction and operation the tracks and equipment were of necessity only in the experimental stages of development, and some tracks had not been constructed sufficiently strong to demonstrate the possibilities of steam railroad transport.

The Delaware & Hudson Canal Company's Railroad was designed and constructed for steam power, but when the locomotive "Stourbridge Lion," built in England, arrived in 1829 and made a short run it was found too heavy for the track, and abandoned, a great disappointment to the advocates of steam power.

Work was commenced upon the Mohawk & Hudson Railroad in 1830, after Stephenson's "Rocket," with its multitubular boiler, at the trials at Rainhill, England, October, 1829, had fulfilled the stipulation and won the prize of five hundred pounds sterling, offered by the Liverpool &

Manchester Railway Company for the best engine, and the result gave a world-wide impulse to steam railroad transportation.

The first ten miles of the Philadelphia & Columbia Railroad, strap rails were laid upon stone sills, which were in continuous parallel lines. The strap iron rails were fifteen feet long and were attached by small spikes driven into cedar plugs in the stone sills. Seventy-one and six tenths (71.6) miles were laid with rolled edge rails with chairs. The strap iron rails and wooden stringers were, however, generally employed for the first railways, but did not form a smooth and substantial track and by their frailty forced our civil and mechanical engineers to develop the American type of locomotive and equipment. They were resourceful men and brought up in the trying school of experience and they proved equal to the great task.

It will be noticed from Table 1 that in 1840 only 2,818 miles had been constructed. Nearly all of the first railroad companies were bankrupt and passed into receivers' hands, owing to the great expense and cost of operating on tracks which had been built as permanent structures to endure for many years, but were destroyed by the generated wheel effects of three to four tons upon the drivers, and one and one-half to two tons on the wheels of the ordinary rolling stock. All of the early strap iron rails were imported from England or Wales, as rolling mills had not been built in this country.

The strap iron rails were increased to one and one-half inches in thickness and three inches in width, and between 1840 and 1850 so many accidents occurred from their use that in New York State, in 1844, their further employment was discontinued.

Robert Stevens, in 1830, for the Camden & Amboy Railroad designed a "T" section of iron rail, nearly similar to those of the present type in use. That is the only form of the early rail which has remained as a survival of the fittest of the many different sections employed. Pear-shaped iron rails were imported from England, and many of these, made out of refined iron, lasted several years under the light wheel loads, but when they increased to ten or twelve thousand pounds upon the drivers the rails failed with great rapidity.

The mileage in 1850 had increased to 30,626 miles on iron rails. The eight-wheeled passenger car was soon followed by the eight-wheeled freight car, constituting, with the four-wheel front truck locomotive, distinct types of American equipment.

The physical properties of the iron were adequate only for the installation of the railroads, but proved inadequate when the driving wheel loads reached ten and twelve thousand pounds, and when the speeds of trains attained twenty-five and thirty miles per hour the iron rails broke and laminated with such rapidity that the operations of the railroads were conducted with great difficulty and expense.

Broken rails were so numerous in the sixties that the railroad officials tried the Booth steel-capped rail, which had a surface of about one-

quarter (¼) in. of crucible steel rolled on to a stem of wrought iron, but the surfaces were not welded and did not last long in the track.

Bessemer's invention to make steel by blowing air for fifteen to twenty minutes through molten iron of five or more tons in a converter and burn out the three to four per cent. carbon of the cast-iron, and subsequently recarburize it, giving it the percentage of carbon required for the steel, was, after some failures, successful. The iron selected had to be low in the impurities, phosphorus and sulphur, for none could be reduced in the acid-lined converter. The output of steel rails was large compared to the output of iron rails.

Bessemer rails were rolled in England and tried by many of the railroads, commencing about 1860, and in 1863 a number of trial orders were placed for similar rails in this country. The cost at the time of one hundred to one hundred and twenty dollars per ton, in gold, to which was added the premium of forty or more per cent. in our currency, forced the railways to use as light a section as possible of the steel. Many of the sections of 56 to 58 lbs. per yard, four inches in height with comparatively a thick base but thin heads, were imported and tried. The steel rails in places of severe service would outlast ten to fifteen of the best iron rails which could be secured. Bessemer steel works were inaugurated in this country about 1866.

The sections were only four to four and one-quarter inches in height, and the deflections of the rails under the passing wheel loads permitted nearly the entire concentration of the wheel load on each cross-tie. The rail sections were not stiff enough to distribute only a small part of the load in the wheel spacing and while the cost of maintenance for track work was high the loss of metal per yard was quite small. The light sections did not permit the development of the wheel loads and enlargement of the locomotives and cars as much as was desired by the railroads for the demands of transportation. The loss of metal per yard in service proved to be so small that the consensus of opinion was general that from the excellent wear of the thin-headed sections a residual section might be designed of sufficient strength to carry the traffic and add to the head the amount of metal desired for wear. The base of the rails were made thinner and fifty per cent. or more of metal put into the heads of the rails. These sections when rolled out of practically the same chemical composition did not give the results of former sections, owing to more massive heads and coarser structure of metal incident to the greater heat units in the metal of the head to cool.

The change in this form of section was made by a committee of Engineers in about 1870 and sections they recommended were in service in 1874. The excellent results which they expected to obtain were not secured in subsequent service and the increased demands of transportation for better and smoother rails that would reduce the generated wheel effects of the moving trains was so important and there was such a diversity of opinion in reference to the sections of rails that in 1878 I designed my Track Indicator and constructed a car in which the measure-

ments of the undulations of the tracks could be made. Passing over several of the important lines, the New York Central & Hudson River Railroad, the Boston & Albany Railroad, Philadelphia & Reading and Baltimore & Ohio, it was found that rails in the track had characteristic permanent sets. These I could classify, and while the railroad companies thought they could make their tracks as smooth as they desired by more ballast and labor, it was shown by repeated inspection of the tracks that while they might temporarily improve the surface of the track it did not remain but a short time before it was more or less out of surface.

One part of the mechanism of the apparatus summed the undulations in the rails under the special truck, into feet and inches per mile, by which a comparison could be made of the different conditions of the track per mile. It also recorded by large diagrams, on a scale of one inch of paper to fifty feet of track, the actual vertical undulations and low joints in the tracks. The conditions or smoothness of the steel was an important factor, and also the stiffness of the rails.

This led to the design of the five (5) in. 80-lb. rail for the New York Central & Hudson River Railroad in 1883, which was rolled and placed in the tracks in 1884. By adding fifteen pounds to the ordinary 65-lb., four and one-half (4½) in. rails, then used for the heaviest service, and making an 80-lb. section, five (5) in. high, the actual stiffness of the section was increased sixty-six per cent. over the ordinary 65-lb., four and one-half in. rail.

There was a great difference of opinion as to what would be the value of the increased stiffness for track purposes, the majority of opinions being that the value obtained would not be equal to the increased cost.

The section was rolled and placed in the tracks in July, 1884, and demonstrated at once that the increased stiffness in the rail was of decided advantage to the stability and capacity of the track, and raised the standard of maintenance.

Several of the Eastern roads adopted either a five (5) in. 80-lb. section or one of heavier weight, the Pennsylvania Railroad making a five (5) in. 85-lb. section.

I made for the Boston & Albany Railroad a five (5) in. 95-lb. section and rolled it out of 0.06 phosphorus and 0.65 carbon steel for their heavy gradients and sharp curvature. They commenced to lay the rail in 1891 and completed the entire line in 1897.

I had stated on my condensed diagrams in 1883, for the Boston & Albany Railroad, after I had designed the five (5) in. 80-lb. rail, and before it was rolled, that it would be possible to reduce the undulations per mile, as measured by my car, to two and one-half feet, or between the fifteenth and sixteenth line on my condensed diagram, by similar stiff sections. When the line was completed in 1897 and I had made the inspection, the average for the entire four hundred miles of track was fifteen and forty-two hundredths on the condensed diagram.

In 1892 my six (6) in. 100-lb. rail was laid through the tunnel of the Harlem Line. This gave a greater stability to the track than was possible in sections with five and one-eighth (5⅛) in. 80-lb. rails.

TONNAGE UPON DIFFERENT WEIGHTS OF RAILS.

The four and one-half-in. 65-lb. section of the New York Central & Hudson River Railroad, in service eight and one-half years in the Fourth Avenue Tunnel, carried 51,000,000 tons, with a loss of about one-quarter of an inch in depth of the metal upon the head of the rail. This was an English make of rail with a heavy base and thin head. The five-in. 80-lb. section which replaced this section was in service eight years and carried 65,000,000 tons, with a loss of about one-eighth of an inch of metal upon the head before it was removed. The six-in. 100-lb. New York Central section, which was rolled in 1892, and replaced the five-in. 80-lb. section, was removed in July, 1899, carried 95,000,000 tons, and is still in yard service. The loss of metal on the top of the head of the rails, in all the sections in the tunnel, was about twice as rapid as it was from the same tonnage outside.

The six-in. 100-lb. section of rail in 1895 of 0.06 phosphorus and 0.65 in carbon on the "Inbound Main" from 1895 until August, 1907, carried 375,000,000 tons with a loss of about one-eighth of an inch in depth on the head of the rail.

The light earlier sections could carry from 60,000,000 to 75,000,000 tons before they were rough and unsuitable for passenger traffic, and when in a location where the tonnage was only 250,000 to 500,000 tons per month, would last in the track many years. The heavier sections which replaced the light ones carried much greater tonnages from the increase in the density of traffic. Their larger area of metal also gave them a capacity for greater tonnages.

The 100-lb. rails in the Fourth Avenue Tunnel at the present time carry daily from one hundred and fifty to two hundred train movements. The tonnage per month is in some places nearly as much as the light rails were subjected to in one or two years' service.

Table 1 shows the increase in freight ton miles from 1890 to 1900, nearly doubled, while it trebled for 1910.

It has often been stated that the reason why the former rails seem to last so well was due to the elimination of the poorer quality of rails by the service in the track. This statement is not the complete explanation. The older rails were cold rolled by the light wheel loads until the surface was sufficiently hardened to bear the recent heavier loads without much increased abrasion. New rails of the same section and practically the same physical properties would, when subjected to heavier wheel loads, lose more of the metal by wear, before the surface was rolled as hard as the former sections, and their rate would be much faster.

It is not considered advisable at the present time to make the composition of the rails which are to be subjected to the present heavy wheel loads so hard that at first they will entirely resist the cold rolling effect

of the passing wheels. It is better to make the physical properties of the rails such that a slight flow of the metal will take place under the various worn wheel treads which will run over the rails, and in this way the surface will accommodate itself to the average treads passing over the heads, the surface becoming gradually hard, and in a short time the flow is practically arrested.

In rails which are too soft the surface may be worn away by the wheel loads before it becomes sufficiently hardened for the long wear, or the drivers slip on the rails, producing a layer so hard as to require their removal from the track.

Table 1 also shows another important matter. The mileage shown for 1830 to 1850 had been constructed mostly with strap iron rails. The mileage 1850 to 1870 was mostly iron rails, though about one-fifth was steel rails. The mileage for 1880 was more than one-half of it laid with steel rails, while that shown for 1890, 1900 and 1910, the mileage would be mostly steel. It would have been impossible to have constructed the mileage shown for 1910 without the invention of Bessemer steel. We have in the United States about 40,000,000 tons of steel in the track, of which 2,500,000 tons are of basic open hearth steel.

The possibility of developing the railroad mileage of the world has been due to a great extent to the study given in all countries to the manufacture of the steel rails. I was a delegate to the International Railway Congress, London, 1895, and Reporter for the United States on the "Nature of Metal for Rails," Sixth Session of the Congress at Paris, 1900. I was also Reporter for America at the Seventh Session of the Congress at Washington, D. C., 1905, on "Rails for Fast Lines," and also a Delegate to the International Congress, Eighth Session, at Berne, 1910. Collecting information for the United States railroads, and being familiar with the practice in England, Germany, France, Belgium and Switzerland, where the wheel loads are much lighter than in the United States, has given me an opportunity to study the comparative tracks in reference to the rail sections and composition in the various countries.

Basic Bessemer steel and Basic open hearth steels are used abroad in Germany, England, also in Africa, and the different delegates stated that the wear on the rails under their light wheel loads, particularly on the curves, was much more rapid than was desired. The temperatures in those countries do not fall as low as they do in our Northern states and Canada. They use higher carbon rails in France as a rule than we do in this country, with excellent effect. Their wheel loads are also much lighter and they maintain their rotundity for a longer period than the wheels here, under our heavier wheel loads and long distance runs.

One of the problems confronting the railroads to-day, in those states where the temperatures fall to 20 and 40 degrees below zero, is to secure a sufficiently homogeneous metal in the 33 and 36-in. wheels for the entire circumference of the tire or wheel tread to maintain its rotundity. The 36-in. wheels make 560.2 revolutions per mile, and with their static load of five tons, the accumulated tonnage upon the tread of the tire or wheel would

be 2,801 tons for each mile run. The tonnage for the run from New York to Chicago would be 2,700,000 tons, from Boston to Chicago, 2,800,000 tons and from New York to St. Louis 3,200,000 tons.

The locomotive drivers of 79 in. in diameter make 255.3 revolutions per mile. The Pacific type engines have static loads of 14.3 tons per driver, consequently the static load per mile run upon the metal is 3,651 tons. These figures are sufficient to show that their tonnage upon each portion of the bearing surface on the tread repeats the load for each revolution and for high speed trains with great rapidity, consequently the accumulated tonnage on the tires and wheels enlarges according to the distance run.

THE EFFECT OF COLD ON RAILS IN A PERMANENT WAY.

First, the direct one which affects the metal, decreasing its ductility but increasing its tensile strength, elastic limits and modulus of elasticity to a slight extent and making it more sensitive to shocks.

Second, indirect effect by contraction of the metal which may set up the tensile stresses of some magnitude in the rails before the ends render in the splice bars. The intensity of this effect on the rails is greater in countries subject to low temperatures near or below zero, and subject to cold waves from the North, where the temperatures fall many degrees below zero, or fall in a short time and continue cold for a few days until broken by a warm wave from a tropical climate.

The experience of the railroads in the Northern and Western states this winter is more severe than ever before experienced. The effects have been so great that rails which have heretofore been quite free from breakages have been rendered more susceptible to the wheel effects of the passing trains and a larger number broken than ever before reported. Such conditions have been studied quite extensively for the purpose to render the rails more ductile or of greater tenacity and toughness to withstand the shock of passing wheels in temperatures of from 20 to 40 degrees below zero.

The service tests of rails of large ductility or tenacity and toughness of metal in large tonnages, scattered in many states, show during the past winter an almost entire freedom from breakages and indicate that much has already been accomplished. It is now possible from a definite chemical composition to determine what ductility or toughness may be secured when the steel is properly purified in the bath, and thus increase the factor of safety in the output of the rails.

To most Engineers of Maintenance of Way who are not conversant fully with the actual steps of the different processes of manufacture it seems that a specification for chemical composition and a few subsequent tests for quality would be sufficient to secure rails to withstand the present service. This is by no means the case, for it is only by a knowledge of the manufacture of the steel and its subsequent use in the track that one obtains the requisite knowledge to provide for the various conditions of service to which rails are subjected.

It is the duty of users of rail to advise the manufacturers of the type and as far as possible the cause of failures and breakages of rails in the tracks.

The gathering of statistics of rail failures of the past few years and discussing them with the manufacturers has resulted in a co-operation to improve the quality of the output.

I was present on the 15th instant at a conference of the Presidents and Rail Manufacturers, in New York, in which the subject was thoroughly discussed. The Presidents from the Northern and Western States stated that they had experienced lower temperatures and for a longer period to that date than had previously occurred in all their experience in railroading. The Eastern roads have experienced the effects of these low temperatures for a number of years and found it necessary to make some preparation for them.

I have been making a series of observations and tests for some years in anticipation of severe climatic conditions, and the recent results seem promising. It has been, however, necessary to develop the manufacture of the steel to the highest state of the art and subject the product to severe tests in the track to see what has been accomplished.

The results so far indicate that decided progress has been made. This has come from a large experience in dealing with tenacity and toughness in rail steels for the past two decades. The results of this work have been carefully studied for the benefit of our service.

Should it seem advisable to supply some illustrations of the early sections to show what work has been required to develop a suitable section for the present railroad service, it would be a pleasure to supply them.

It must be remembered that with the present wheel loads and high speeds of the train movements, the time factor for reversal of the stresses under the wheels and in the wheel spacing has been materially shortened by the present schedules.

The wheel loads also require stresses of large magnitude to be distributed in a shorter time than was necessary with slower speeds and lesser wheel loads.

The question of recent sections will be treated more in detail by Mr. Johnson in Part II, and specifications by Mr. Cushing in Part III.

TABLE I.

	1830	1840	1850	1860	1870	1880	1890	1900	1910
Miles of lines operated exclusive of side tracks, yards and terminals	23	2,818	9,021	30,626	52,922	93,296	163,597	192,556	239,652
Miles of all tracks							199,875	258,784	349,159
Tons of freight one mile							76,207,047	141,599,159	255,528,643
Passengers one mile							11,847,785	16,039,007	33,949,936
Locomotive weights without tenders (tons)							1,265,880	2,023,702	4,271,000
Freight cars—total capacity (tons)							19,288,301	37,210,720	74,043,000

Part II.

STEEL RAILS.

INVESTIGATIONS BY THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

BY THOS. H. JOHNSON.

The first action taken by an organized body of engineers in relation to the character and quality of the rails used on the railroads of this country was had by the American Society of Civil Engineers in 1874, in the appointment of a Committee to investigate and report on "The Form, Weight, Manufacture and Life of Rails."

This Committee made a progress report in June, 1874, again in May, 1875, and a final report in June, 1876.

At these dates the use of steel rails was in its infancy, and comparatively few had been laid on American railroads. Such as had been laid had been down too short a time to warrant the Committee in drawing conclusions in regard to them; hence, the reports of this Committee dealt almost exclusively with iron rails, with only incidental reference to the use of steel, and therefore they have no bearing on the questions now before us.

Steel rails first appeared as an established commodity in the market reports in 1868. From the first they rapidly began to displace the old iron rails, and in 1882 the latter had ceased to appear as a market commodity.

Sections.

During the first fifty years of railroad development many different sections had come into use, and there was no common standard. In 1887 the American Society of Civil Engineers again appointed a Committee, this time charged to consider "the proper relation to each other of the sections of rails and wheels." This Committee made a progress report in 1888, and a final report in 1889, and in the following year, 1890, following the subject still further, another Committee was appointed to prepare and submit to the Society a series of "Standard Sections," for rails of different weights per yard.

The Committee made a preliminary report in 1891, and a final report in 1893. This latter report was accompanied by a series of sections for rails, weighing from 40 lbs. to 100 lbs. per yard, varying by intervals of 5 lbs. These sections were approved by the Society, and promulgated as the "A.S.C.E. Standard Sections."

They met with favor and were adopted by many railroads, so that in a very few years about two-thirds of the output of the rail mills conformed to those sections.

Specifications.

As might be expected, with the engineers of the country acting independently, with imperfect understanding as to the effect on the finished product of different elements in different proportions, accented by more or less variation in the process, as practiced at different mills, a large number of specifications came into existence, differing in their requirements as to chemistry and physical requirements.

The oldest specification now before the writer bears date 1876, and makes no mention of the chemistry. It required a tensile test from each heat, the test piece to be cut from the head of the rail.

The next issue of the same specification, 1879, requires that the carbon shall be between 0.30 and 0.50 per cent., but it is silent as to other elements. In later issues, manganese and phosphorus were added, and still later silicon.

This is probably typical of the process of development of rail specifications generally, but, as already stated, the resulting specifications differed from each other in many respects.

With the growing prosperity of the country, there was an increasing demand on the transportation facilities, which led to a gradual increase in the weights of rolling stock. This was met by the engineers by correspondingly increasing the strength of the rails. But it was soon found that the larger sections wore out faster on curves than the smaller sections had done. This was due to the fact the larger sections cooled more slowly and underwent a partial annealing rendering the metal softer and less resistant to the grinding action of the flanges against the side of the head. Some engineers sought to remedy this by specifying an increased proportion of carbon, varying with the size of the section. This added still further to the diversity of the specifications.

Part III.

THE QUESTION OF THE IMPROVEMENT OF RAIL DESIGN AND SPECIFICATIONS, FROM 1893 TO THE PRESENT TIME.

BY W. C. CUSHING.

The period between 1893, the year of the adoption of the standard rail sections of the American Society of Civil Engineers, and the First Annual Convention of the American Railway Engineering and Maintenance of Way Association in 1900, was occupied by the railway engineers in the study of the behavior in the track of the rails rolled according to the new designs, which were rapidly put into service by the different railroads of the country.

A preliminary meeting of the railway engineers was held in Chicago on October 21, 1898, for the purpose of organizing the American Railway Engineering and Maintenance of Way Association, and at that meeting a committee was appointed to draft the Constitution and By-Laws.

On March 30, 1899, the permanent organization of the Association was effected in Buffalo, by the adoption of the Constitution and the election of officers.

As stated in the Constitution, the object of the Association was the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railroads, and the means to be employed for this purpose were to be:

(1) Meetings for the reading and discussion of papers, and social intercourse.

(2) The investigation of matters pertaining to the objects of the Association, through Standing and Special Committees.

(3) The publication of papers, reports and discussions.

The real and final object was, however, for the members to exchange information and experience with each other and to bring about the unification, as much as possible, of specifications for the purchase of the large amount of material and supplies used by railroads, which ought to result in the mutual benefit of the manufacturers and the railway companies.

In order to hear the first reports of Standing Committees, the first convention was held in March, 1900, in Chicago, and among the Standing Committees was one on Rail.

The report of the Committee was largely historical, but it was developed at that and subsequent meetings that the subject was going to be

one of the most important and most interesting of those to come before the Association in the future, and in closing the discussion, the President said:

"Of course, we realize that we do not expect to exhaust the subject at this meeting, or in the next, or in our lifetime, but we are simply laying the foundation now for our future work, and I presume at the next meeting the Committee will not be still 'fuller' than they are now, but that there will be more of them present and that they will continue the consideration of this matter."

The work of the Committee of the American Society of Civil Engineers was undertaken with the object of improving the design or cross-section of rails, and did not undertake the preparation of specifications for their manufacture or inspection, but each railway company issued its own specifications, which were not specifications for manufacture, but for inspection. These specifications differed from each other in various details, such as the method of testing, the allowable variations from the templates, the smoothness of the surface and the workmanship generally, while but little was said about the chemical composition. Indeed, this state of affairs must have been quite annoying and expensive to the rail manufacturers, and, as all railroads were striving for exactly the same object, viz., to obtain the best material which would make an absolutely safe steel rail, the unification of the specifications seemed to be very desirable, and if it could be brought about, the existence of the Association would be entirely justified.

At the Annual Convention in 1901, it was ascertained that the rail sections or designs of the American Society of Civil Engineers were in use by about 70 per cent. of the railroads of the country, and it soon developed in the discussion that the rail steel in use by the railroads was not giving very good satisfaction. This dissatisfaction pertained to all sections of rails, and the railway engineers thought that the trouble was largely due to the temperature of rolling being entirely too high, leading to the expression of one member that "the material was squirted through the rolls." The engineers of the rail manufacturers, who were also members of the Association, contended, on the other hand, that the fault was due to the rail sections, and especially to the thin base designs of the American Society of Civil Engineers. It thus developed that the railway engineers believed the trouble was entirely due to improper processes of manufacture, while the rail manufacturers' engineers placed the fault on the design of the rail cross-section.

It was apparent, therefore, that the committee must study both the question of design and the question of rail manufacture, the latter with the special object of devising tests and methods of inspection which would more surely determine whether the material came up to the requirements of service or not. It was quite evident that this work would be of long

duration, because it was necessary that more study than ever before should be placed upon both the question of rail design and its manufacture, and it would be necessary to proceed slowly and carefully, in order to avoid the misinterpretation of statistics and information. Sir Lowthian Bell is reported to have said, at the London meeting of the American Society of Civil Engineers, in 1900, that "As he had been 25 years a manufacturer of rails and 25 years a director in the North Eastern Railway, he represented both maker and user, and he had at his disposal 35,000 analyses to go upon in making deductions. From these he could prove and disprove everything that could be said for or against any composition of a rail—a facility beloved by the expert." It is well for any investigator not to forget Sir Lowthian Bell's remark. It has been brought home to the Rail Committee many times in its prolonged investigation.

Prior to this time, so much had been said by railway engineers about the necessity for rolling at lower temperature that, in 1900, the Kennedy-Morrison process of holding rails just before the final passes until they came to the desired temperature, after which they were put through the final passes at that temperature, was introduced by the Carnegie Steel Company, and great expectations of the value of the results were held. At the same time other rail manufacturers began rolling at lower temperature and claimed to accomplish the same results. The process did not, however, give the results expected, as the effect was only skin deep, for when the skin wore off, the ordinary metal was exposed underneath. The rails rolled after its introduction developed rather more failures than usual, and since that time the value of rolling at low temperature has been rather uncertain. This experience is mentioned to show that the value of many changes in process of manufacture can only be developed after long experience, which is one of the reasons why an investigation of this kind is bound to cover a long period of time.

In 1895, at Zurich, Switzerland, the International Association for Testing Materials was organized to bring about "the development and unification of standard methods of testing, for the determination of the properties of materials of construction, and of other materials, and also the perfection of apparatus for that purpose." On June 16, 1898, or but a few months prior to the organization of the American Railway Engineering and Maintenance of Way Association, there was formed, at Philadelphia, the American section of the International Association, which, a few years later, was renamed "The American Society for Testing Materials." The American section was composed of manufacturers as well as of consulting engineers, railway engineers, and others, and had already begun the study of rail specifications. Therefore, at its Annual Convention in 1901 the Rail Committee of the American Railway Engineering Association submitted the rail specifications recommended by the American Branch of the International Association for discussion, in order to get the subject under way.

Specifications for steel rails have always consisted of three general parts:

(1) Chemical requirements or properties;
(2) Physical requirements; and
(3) Details of manufacture.

Up to that time the various railway companies emphasized one or more of these parts, according to their individual preference or experience. Some almost ignored the chemical requirements, others were more or less elaborate in their physical requirements, while some barely touched upon details of manufacture, and others treated the subject quite elaborately.

Chemical Requirements or Properties.

The chemical properties of these proposed specifications for Bessemer steel rails were those of the Carnegie Steel Company, and they are to-day the standard chemical specifications of all the steel rail manufacturers, and of the American Society for Testing Materials, with scarcely any alterations. They were as follows:

	50–60 lbs.	60–70 lbs.	70–80 lbs.	80–90 lbs.	90-100 lbs.
Carbon	.35 to .45	.38 to .48	.40 to . 50	.43 to .53	.45 to .55
Phosphorus, not over	.10	.10	.10	.10	.10
Silicon, not over	.20	.20	.20	.20	.20
Manganese	.70–1.00	.70–1.00	.75–1.05	.80–1.10	.80–1.10

The specifications for foreign use were practically the same.

The only changes which have been made in these specifications by the steel manufacturers and by the American Society for Testing Materials up to the present time are to make the carbon for 60 to 70-lb. rail .35 to .45, and the manganese for 90 to 100-lb. rail .84 to 1.14.

With few exceptions, the railroads of the United States have accepted these chemical constituents as recommended by the rail manufacturers, because they have considered that the chemical properties were only a minor part of the specifications for rail steel, compared with the physical requirements.

To show that the railway engineers have been justified in taking this view of the matter, the following quotation is made from an article in the Journal of the Franklin Institute for 1889, by Capt. R. W. Hunt, once a manufacturer of steel rails and now a steel rail inspector of wide experience:

"Rails made by John Brown & Co. of England, and put down on American railroads some years ago, have been generally held up as ideal rails, and the American makers for a long time supposed that when these rails did wear out so that they could be analyzed the secret of their good service would be told. As an illustration of how little regularity or purity of chemical composition influenced the wear, I call your attention to the analyses of thirteen of John Brown rails, all of which had filled years of faithful service and have been selected as bright examples of what good rails should be:

	C.	Si.	Ph.	S.	Mn.	Cu.
1	0.35	0.08	0.128	0.068	0.742	0 048
2	0.39	0.071	0.156	0.155	0.662	0.32
3	0.36	0.103	0.125	0.060	0.815	Trace
4	0.70	0.306	0.111	0 008	0.681	0.016
5	0.36	0.069	0.153	0.131	0.621	0.143
6	0.44	0.208	0.098	0.059	1.046	None
7	0 45	0.102	0.128	0.105	0.616	0.056
8	0.36	0.087	0.148	0.181	0.625	None
9	0.24	0 068	0.131	0.104	0.645	0.005
10	0.37	0.051	0.096	0.050	0.639	Trace
11	0.32	0.089	0.145	0.077	0.745	Trace
12	0.35	0.069	0.077	0.099	0.945	None
13	0.28	0.032	0.084	0.053	0 312	None

"You will observe that carbon ranged from 0.24 to 0.70; silicon from 0.032 to 0.306; phosphorus from 0.077 to 0.156; sulphur from 0.050 to 0.155, and manganese from 0.312 to 1.046.

"These 13 rails, taken as a whole, were chemically a 'poor lot,' but physically most excellent."

Physical Properties.

Two general methods for testing the physical requirements had been in use up to the year 1900, viz., a bending test of a small bar ½ in. to ¾ in. square and 10 in. to 20 in. long, and a drop test, which consisted in letting fall a weight of about 2,000 lbs. on a piece of rail with a span of 3 to 4 feet. Some railways used one method, some the other and some both, but by 1900 the small bar test had been generally abandoned in favor of the drop test.

It was customary to make a test of *every fifth heat* of steel, and to let the weight fall from varying heights, according to the pleasure of the maker of the specifications. The proposed specifications of the American branch retained this method of testing the physical properties by dropping the weight of 2,000 lbs. on every fifth heat of steel, from a height of 16 ft. for rail weighing 55 to 65 lbs. per yard, 17 ft. for rail weighing 65 to 75 lbs. per yard, 18 ft. for rail weighing 75 to 85 lbs. per yard, and 19 ft. the rail weighing 85 to 100 lbs. per yard, but these conditions were not accepted by the American Railway Engineering Association, as there was a strong feeling among the railway engineers that more severe conditions of testing were necessary. They felt that the chemical properties could be left to the greater experience and chemical knowledge of the rail manufacturers, but that they must be the ones to prescribe the physical tests which the finished rails must stand in order to be accepted for such important service as carrying the railway traffic of the country. In 1904, therefore, the Engineering Association decided that *each heat*, instead of *every fifth heat* of steel, must be tested, and that the height of the drop should be increased.

It was also ascertained that the rail butts heretofore tested under the falling weight had been from the bottom of the ingot, and it was now made a part of the specifications that the test piece should be taken from

the top of the ingot, on account of the probability that the metal would be less perfect at that end.

Testing every heat instead of every fifth heat, as formerly, was considered little short of a revolution in the method of testing at that time.

Details of Manufacture.

Except in the case of a few companies, the specifications in regard to details of manufacture were not elaborate, the specifications being confined almost entirely to allowing for variations from the standard template and from the length of the rail, to smoothness and perfection of finish, to branding, etc.

In view of the agitation for colder rolling, the Pennsylvania Railroad had introduced into its specifications in 1900 a clause requiring that the rail at the last pass should be at a red heat, preferably a dull red, but in 1901 they replaced it with a so-called "Shrinkage Clause," which was intended to control the temperature of the rail when being finished, by prescribing that the shrinkage, after the rail was sawed, should not exceed a certain number of inches. This clause was also introduced into the proposed specifications of the Engineering Association, making an additional requirement in the details of manufacture.

Lately there has been a great deal of argument on the part of the rail manufacturers to have the railway engineers specify a definite percentage of discard from the ingot, in order to cut off material which is more subject to segregation and more liable to have interior defects from the shrinkage cavity, gas bubbles, etc., but the railway engineers have rigidly set their faces against such a requirement, because they feel that they are much better safeguarded by the clause introduced into the specifications of the American branch of the International Association of Testing Materials, which was that "sufficient material should be discarded from the top of the ingots to insure sound rails."

When that clause was adopted, in 1901, and for a number of years afterwards, the positions of the rail manufacturers and the railway engineers were reversed, the railway engineers believing that it was best to specify a definite amount of discard, while the rail manufacturers took the opposite view. It was well expressed by an engineer of one of the steel companies, who said: "I do not think this Association, nor any other, should state definitely how much should be sheared from the bloom. The matter is entirely one-sided. If we agree here that 25 per cent. shall be sheared from the bloom, we might assume that would settle it, but it will not. The Association will be perfectly safe in making the claim that sufficient shearing will be done to eliminate piping. If the manufacturers can remove the piping by shearing 15 per cent., they will not agree to shear 25 per cent. The object in shearing is to get rid of the piping, and the only matter of agreement will be to reach the point where sufficient shearing is done to remove the piping. For that reason, I think the Association will make a mistake to demand that 25 per cent. be sheared off."

The railway engineers of to-day unanimously agree with that point of view, and their positon has been further strengthened by an additional

test, which will be described later. Furthermore, the records of rail failures which have been kept for a number of years disclose the incontrovertible fact that, where a 15 per cent. discard might do for one ingot, 50 per cent. would not be adequate for another.

In 1902, the American Society of Civil Engineers deemed it advisable, in view of the continual criticism of the sections of rail which they had previously designed, to take up once more the study both of rail design and specifications, and accordingly a committee was appointed for the purpose.

The Committee of the American Society for Testing Materials also continued its study of the rail question, and joint meetings of all three committees were held so that each would derive benefit from the work of the other.

On April 25, 1906, the Committee on Standard Rail and Wheel Sections was appointed by the American Railway Association, and on October 24, 1906, the Committee was directed to report in addition on the subject of specifications for the manufacture of steel rails, in connection with its report on standard sections. The rail manufacturers were asked to co-operate with the committee by sending representatives to study the question with it at its meetings, and in addition the committee employed disinterested men of national reputation in their knowledge of steel making and the properties of steel, to give expert advice on the subject. After many meetings together a report was submitted, October 30, 1907, containing the recommended rail sections and specifications, both for Bessemer and Open Hearth steel.

Further advice was obtained from disinterested persons who had a wide knowledge of the properties of steel and its manufacture, and final report was submitted by the committee on April 22, 1908, with the recommendation that there were many details of the development and the following up of the results in service of the new types of section, rolled under the new specifications, which would require considerable time and much careful study, and that they could be more efficiently and more appropriately handled by the American Railway Engineering Association. The sections and specifications were, therefore, referred to the American Railway Engineering Association, with the request that they follow up the question in its various details and keep a careful record of the results, with a view to determining whether any changes should be made, either in the specifications or designs.

As the question of discard was dealt with in these reports quite fully, it is advisable to make quotations therefrom, because the earnest consideration given to the question led to the development of an additional test, which is considered of great importance in determining the quality of metal by eliminating a large number of the so-called "piped rails," or rails with interior defects:

"In the matter of discard, there was a desire on the part of the railroad members to arrange for a greater discard, and a strong disposition to insist upon a uniform minimum percentage. The manufacturers, how-

ever, presented considerable evidence which tended to show that a fixed minimum percentage requirement would be not only unfair but unscientific, claiming that the extent of piping and segregation is influenced by the size of the ingot, the rate of pouring into the mould, and other details of mill practice. . . . . .

"With regard to the discard question, the Committee has always been of the opinion that it would be preferable to test the finished product rather than specify as to details of mill manufacture. . . . . .

"In pursuing its investigation of this discard question, the Committee received a suggestion from Mr. Wm. Metcalf to the effect that it would be reasonably practicable to apply the above theory to the manufacture of rails by arranging to test to destruction a number of rail butts representing a certain portion of the total output, and to base rejections on the results of these tests. . . . . .

"In order to avoid the unnecessary waste of good material, the Committee set about to devise means by which the rejection of defective material could be insured without requiring an arbitrary and definite percentage of discard in every case, and a Committee of the Pennsylvania Railroad System pursuing the same line of investigation had adopted a tentative specification which provided for a physical test of this nature, and which further provided that when physical defects were discovered all top rails of the heat should be rejected. This would result in a discard of about 25 per cent. to 30 per cent. of the entire metal in the heat whenever physical defects were discovered, and it was felt that a requirement of this nature would not only provide for the rejection of defective material, but would insure the greatest care on the part of the manufacturer.

"A trial lot of the rails of a section corresponding to Type 'B' was recently rolled under these specifications as to discard, and the results convinced the Committee that a development of this idea would prove the best solution of the discard problem."

In connection with the Details of Manufacture, an important addition was made by requiring that the brand on the rail should also contain a letter marking the position which the rail originally occupied in the ingot, so as to enable a study to be made of the effect of that position.

On June 5, 1907, a committee of the Civil and Mechanical Engineers of the Pennsylvania Railroad System and two rail manufacturers was appointed to take up the study of the rail question, and design new rail sections and recommend new specifications, with the object of improving the quality of the material used in rails manufactured for that System.

The first meeting was held on June 12, 1907, and the new rail designs, known as the "P. S." sections, were adopted on September 20, 1907. Tentative specifications were recommended on November 15, 1907, and 10,000 tons of rail rolled in accordance therewith. They were subsequently modified, on criticism of the manufacturers, and issued February 4, 1908.

The new rail designs of the Pennsylvania Railroad System and the American Railway Association provided for a more even distribution of the metal in the head, web and base, and for a thicker base, to meet the

views of the rail manufacturers, who believed that a better distribution of the metal would result in an improved quality, due to more favorable rolling conditions. All of these sections are still in service and are being closely watched to determine whether the expected improvement will be realized.

The Pennsylvania Railroad System specifications have been modified several times, in the light of additional experience, and contain the improvements which have been brought about from time to time through the experiences and researches of its own committee and the committees of the other associations.

So far as the chemical requirements are concerned, they are practically the same as adopted by the Rail Manufacturers, and other associations.

The Physical Requirements are determined by the Drop Test with the standard machine, and, in addition, the test piece is nicked and broken to reveal the presence or absence of interior defect.

In the Details of Manufacture, the discard is required to be sufficient to secure sound rails, and the shrinkage clause to regulate the temperature of rolling is retained. The rails are marked for position in the ingot, for the purpose of subsequent identification, in order to study the effect of that position.

Similar studies and investigations are being conducted by the New York Central Lines, the Harriman Lines, Baltimore & Ohio Railroad Norfolk & Western Railway, Lehigh Valley Railroad, Reading Railway and other companies, and the specifications are being improved as new knowledge is obtained. The first named company has been foremost in the study of the effect of Titanium in steel making.

Through the assignment of the rail question to the American Railway Engineering Association by the American Railway Association, the work of the Committee was given an official character, and its real work commenced. The first thing of importance accomplished was the introduction of a standard drop testing machine at all the rail mills, so that the results obtained at any one mill were comparable with those obtained at any other. Up to that time, 1908, machines of different design and setting were used, and the results were unreliable. With the year 1909 began the collection of a large amount of information, obtained from research work, bearing on the disputed points of rail manufacture, and on proving or testing.

In 1910, the specifications for Bessemer rail formerly adopted by the American Railway Engineering Association were withdrawn, and new ones, for both Bessemer and Open Hearth, were presented for consideration by the Association, which embodied all the improvements in the methods of determining the physical properties and the details of manufacture which had been brought forward up to that time. It was recognized, however, that numerous disputed points could only be cleared up by experimental research conducted by a trained engineer physicist, and accordingly such an investigator was added to the Committee to devote all

his time to that work. The Engineer of Tests, M. H. Wickhorst, since his appointment, has been constantly busy with research work, and has added a great deal to our knowledge of the subject.

He has made reports on the following subjects:

Influence of Carbon on Deflection.

Drop, Bending and Tensile Tests on Bessemer, Titanium Bessemer, and Open-Hearth Rails, rolled by different mills, including chemical analyses and etched sections.

Investigation of a Split Head Rail.

Segregation, as Influenced by Fire Clay on Ingot.

Strength of Rail Head.

Drop Tests of Rails—Effect of Impact Energy variously distributed.

Flow of Rail Heads under Wheel Loads.

Segregation and other Rail Properties as influenced by Size of Ingot

Tests of Steel Rail Ingots and derivative shapes made at Watertown Arsenal.

Influence of Rolling Temperature on the Properties of Bessemer Rails.

In all of this work, Mr. Wickhorst has been afforded every facility by the rail manufacturers for carrying on the investigations, and their machinery, material and laboratory assistants have been placed at his disposal. In addition, their officers have been freely consulted by the Committee, and have attended some of its meetings.

While at the present time the American Railway Engineering Association has not adopted standard specifications for rails, yet it has had constantly before it for consideration and study a set of proposed specifications which have embodied the best knowledge of the subject, and they have been changed from time to time in the light of new experimental investigation. The most energy has been devoted to the improvement of methods of testing to determine the physical properties, and practically no changes have been made in the chemical requirements from the standard specifications of the rail manufacturers. The railway engineers prefer to subject the finished material to such tests as will cast aside the defective rails. Their specifications, therefore, include many additional tests over those in use ten years ago. The results of the work of the American Railway Engineering Association have been closely followed by the Railway Companies and *vice versa,* so that the specifications of the Railway Companies have been improved from time to time, and now embody the additional tests devised. Rails have been rolled in accordance with these new specifications for several years, and it is believed that a marked improvement is apparent in the rails being laid in the tracks since their adoption.

February, 1912.

REPORT OF COMMITTEE XVII—ON WOOD PRESERVATION.

EARL STIMSON, *Chairman;*
G. M. DAVIDSON.
H. B. DICK.
W. W. DRINKER.
DR. W. K. HATT.
V. K. HENDRICKS.
GEORGE E. REX.
E. H. BOWSER, *Vice-Chairman;*
E. A. STERLING.
C. M. TAYLOR.
DR. H. VON SCHRENK.
CHARLES YODER.
C. E. KNICKERBOCKER.
Committee.

To the Members of the American Railway Engineering Association:

The Board of Direction assigned to your Committee the following subjects:

(1) Continue investigation of the proper grouping of the different timbers for antiseptic treatment.

(2) Compile available information from service tests.

(3) Investigate the merits of various preservatives, giving special attention to oil from water as tar and to the use of refined coal-tar in creosote oil.

(4) Report on the advisability of revising the adopted specifications for creosote oil.

(5) Recommend forms for the inspection of preservative processes.

(6) Present specifications for impregnation with creosote oil.

(7) Report on the value of impregnation with crude oil.

(8) Report on the value of brush coating and dipping.

A Sub-Committee was assigned to the consideration of each one of these subjects.

Two meetings of the Committee were held at the Association rooms, Chicago; one on October 11, 1911, those present being Earl Stimson, Chairman; E. H. Bowser, Vice-Chairman; H. B. Dick, Dr. W. K. Hatt, V. K. Hendricks, George E. Rex, E. A. Sterling, C. M. Taylor, Dr. H. von Schrenk, C. E. Knickerbocker; the other meeting on December 7, 1911, those present being Earl Stimson, Chairman; E. H. Bowser, Vice-Chairman; V. K. Hendricks, G. M. Davidson, Dr. W. K. Hatt, H. B. Dick, E. A. Sterling, C. M. Taylor.

(1) GROUPING OF TIMBERS FOR ANTISEPTIC TREATMENT.

The Sub-Committee on Grouping was instructed to continue the investigations of the proper grouping of timbers for antiseptic treatment. Last year arrangements were made for a series of co-operative experiments at several plants to determine the best method of grouping various

species in different regions. These tests have not been completed, but some progress has been made, the results of which are submitted as Appendix "A" to this report. During the coming year additional experimental work will be done at several plants. This work will be systematized, so that uniform results will be obtained and as definite a basis as possible established for grouping under representative conditions.

Considerable time must elapse before the experimental work will be brought to a point where final conclusions can be drawn. Past experience, however, has demonstrated certain fundamental facts in relation to grouping, and it is recommended that such principles as have received recognition in standard practice be embodied in the Manual. These fundamentals can be elaborated upon in the future as additional information becomes available.

The principles recommended at the present time for insertion in the Manual are as follows:

(1) Ties of approximately the same period of seasoning should be grouped together for treatment; green ties should never be mixed with seasoned ones.

(2) Pine ties should be separated on the basis of heartwood and sapwood; it would also be advisable in some cases to group hardwoods on the same basis, but it is not generally practical to do so.

(3) Grouping on the basis of species and families, as, for example, red oaks, pines, beeches, etc., if a further division into hardwood classes is made with pine, is usually a satisfactory practice. From this it follows that red oak, beech, long-leaf pine, loblolly pine and gum should be treated separately. Birch and hard maples and certain other combinations, depending on the locality, can be grouped together to advantage.

(4) The separation in the yard, on the basis the ties are to be grouped for treatment, is an essential and economical practice.

(2) RECORDS FROM SERVICE TESTS.

The recommendations of the report of the Committee for 1911 included the recommendation that certain sections of track be selected on each railroad for the purpose of making accurate tests covering the life of treated and untreated ties. To ascertain the extent to which this had been done in the past, and the results which have been obtained, the Committee sent out a circular letter, the replies to which are abstracted in Appendix "B" to this report.

(3) MERITS OF VARIOUS PRESERVATIVES.

Your Committee was directed to give special attention to the merits of oil from water gas tar and to the use of refined coal-tar in creosote oil. Sufficient information has not been obtained to enable report to be made on these subjects at this time. The investigations will be continued the coming year.

(4) REVISION OF THE ADOPTED SPECIFICATIONS FOR CREOSOTE OIL.

After careful consideration it seems desirable to change the first clause in the adopted Specifications for Creosote Oil to provide that it shall be a pure product from coal gas tar or coke oven tar and free from any foreign admixture, including coal gas tar or coke oven tar.

With this change, the entire specifications for creosote oil will read as follows:

STANDARD SPECIFICATIONS FOR CREOSOTE OIL.

The oil used shall be the best obtainable grade of coal-tar creosote; that is, it shall be a pure product obtained from coal gas tar or coke oven tar and shall be free from any tar, oil or residue obtained from petroleum or any other source, including coal gas tar or coke oven tar; it shall be completely liquid at thirty-eight (38) degrees centigrade and shall be free from suspended matter; the specific gravity of the oil at thirty-eight (38) degrees centigrade shall be at least 1.03. When distilled by the common method—that is, using an eight (8) ounce retort, asbestos covered, with standard thermometer, bulb one-half (½) inch above the surface of the oil—the creosote, calculated on the basis of the dry oil, shall give no distillate below two hundred (200) degrees centigrade, not more than five (5) per cent. below two hundred and ten (210) degrees centigrade, not more than twenty-five (25) per cent. below two hundred and thirty-five (235) degrees centigrade, and the residue above three hundred and fifty-five (355) degrees centigrade, if it exceeds five (5) per cent. in quantity, shall be soft. The oil shall not contain more than three (3) per cent. water.

In addition to the above standard specification, the two following grades can be used in cases where the higher grade oil cannot be procured. It should be understood that where it is necessary to purchase grades No. 2 and No. 3 consideration should be given to the use of a greater quantity of creosote oil per cubic foot.

SPECIFICATIONS FOR NO. 2 GRADE CREOSOTE OIL.

The oil used shall be the best obtainable grade of coal-tar creosote: that is, it shall be a pure product obtained from coal gas tar or coke oven tar, and shall be free from any tar, oil or residue obtained from petroleum or any other source, including coal gas tar or coke oven tar; it shall be completely liquid at thirty-eight (38) degrees centigrade and shall be free from suspended matter; the specific gravity of the oil at thirty-eight (38) degrees centigrade shall be at least 1.03. When distilled by the common method—that is, using an eight (8) ounce retort, asbestos covered, with standard thermometer, bulb one-half (½) inch above the surface of the oil—the creosote, calculated on the basis of the dry oil, shall give not more than eight (8) per cent. distillate below two hundred and ten (210) degrees centigrade, not more than thirty-five (35) per cent. below two hundred and thirty-five (235) degrees centigrade, and the residue above three hundred and fifty-five (355) degrees centigrade, if it exceeds five (5) per cent. in quantity, shall be soft The oil shall not contain more than three per cent. water.

SPECIFICATIONS FOR NO. 3 GRADE CREOSOTE OIL.

The oil shall be the best obtainable grade of coal-tar creosote; that is, it shall be a pure product obtained from coal gas tar or coke oven

tar and shall be free from any tar, oil or residue obtained from petroleum or any other source, including coal gas tar or coke oven tar; it shall be completely liquid at thirty-eight (38) degrees centigrade and shall be free from suspended matter; the specific gravity of the oil at thirty-eight (38) degrees centigrade shall be at least 1.025. When distilled by the common method—that is, using an eight (8) ounce retort, asbestos covered, with standard thermometer, bulb one-half (½) inch above the surface of the oil—the creosote, calculated on the basis of the dry oil, shall give not more than ten (10) per cent. distillate below two hundred and ten (210) degrees centigrade, not more than forty (40) per cent. below two hundred and thirty-five (235) degrees centigrade, and the residue above three hundred and fifty-five (355) degrees centigrade, if it exceeds five (5) per cent. in quantity, shall be soft. The oil shall not contain more than three (3) per cent. water.

No change is recommended at this time in the "Specifications for Analysis of Creosote Oil," except that this heading should be changed to read "Specifications for the Fractionation of Creosote Oil." This specification merely covers the fractionation and does not cover the chemical analysis which would be necessary in order to determine the presence of adulteration. The determination in regard to adulterants can be made chemically in several manners with the same results, and there does not, therefore, seem to be the necessity for preparing a complete specification covering chemical analysis that there is for preparing the specification covering the fractionation, the latter giving different results when made by different methods.

For the purpose of obtaining more information in regard to the relative merits of the flask and retort for the fractionation of creosote oil, and also for the purpose of obtaining other information on which to base further consideration of the specification for fractionation, it has been arranged that various samples of creosote oil be submitted to the various railroads for analysis by various methods, the reports obtained being submitted in writing to the Committee as soon as possible for action by the Committee next year.

(5) FORMS FOR REPORTING INSPECTION.

It is found that the various railroad and timber-treating companies have their own forms for the inspection and recording of the various preservative processes, each meeting their own peculiar conditions, although similar in the essential details. Your Committee is not now prepared to submit report on this subject, but will continue its consideration the coming year.

(6) SPECIFICATION FOR IMPREGNATION WITH CREOSOTE OIL.

A specification for impregnation with creosote oil has already been adopted by the Association and is contained in the Manual. It is the sense of your Committee that this specification is in accordance with good practice, and no change is recommended.

(7) VALUE OF IMPREGNATION WITH CRUDE OIL.

Your Committee is not in position to report at this time and recommends the continuance of the subject for the coming year.

(8) VALUE OF BRUSH COATING AND DIPPING.

A circular letter was sent out making inquiry as to these methods of treatment. Out of thirty-eight replies, thirty-one report that neither process has been used, and seven report that no definite conclusions can be drawn from their experience. It is recommended that further consideration be given this subject.

CONCLUSIONS.

It is recommended:

(1) That the four principles of Grouping of Timbers, as given under subhead (1), Grouping of Timbers for Antiseptic Treatment, be accepted for insertion in the Manual.

(2) That the revised Standard Specifications for Creosote Oil, and the Specifications for No. 2 Grade and No. 3 Grade Creosote Oil, as given under subhead (4), Revision of Adopted Specifications for Creosote Oil, be adopted.

(3) That the heading "Specifications for Analysis of Creosote Oil," as it now stands in the Manual, be changed to read as follows: "Specifications for the Fractionation of Creosote Oil."

OUTLINE OF WORK FOR 1912.

Your Committee recommends:

(1) Continue investigations of the merits as a preservative of oil from water gas and the use of refined coal-tar in creosote oil.

(2) Continue the compilation of available information from Service Tests.

(3) Continue the investigation of the proper grouping of the different timbers for antiseptic treatment.

(4) Continue consideration of the revision of the Specifications for Fractionation of Creosote Oil.

(5) Report on the value of impregnation with crude oil.

(6) Report on the value of brush coating and dipping.

(7) Report on methods of accurately determining the absorption of creosote oil, including check of gage readings and the keeping of corrected records.

(8) That the Board of Direction assign the work of drawing up a Standard Specification for Timber for Treatment to a Joint Committee of the Committee on Wood Preservation and the Committee on Grading of Lumber.

Respectfully submitted,

COMMITTEE ON WOOD PRESERVATION.

Appendix A.

GROUPING OF TIMBERS FOR ANTISEPTIC TREATMENT.

CHICAGO TIE AND TIMBER PRESERVING COMPANY.

The information furnished by this company covers the treatment of red oak and mixed beech ties by the Card process. The weights as given in the table are not taken from selected lots, but cover the daily practice. The cubical contents in each charge was estimated by displacement. The computations from the daily log sheets were made by the Forest Products Laboratory:

Oak—Card Process.			Beech (mixed)—Card Process (includes gum, elm, basswood, etc.)		
Weight per cu. ft. Pounds	Absorption per cu. ft. Pounds	No. Ties used	Weight per cu. ft. Pounds	Absorption per cu. ft. Pounds	No. Ties used
42	14.6	2,670	37	20.6	567
43	14.3	7,516	38	18.7	1,723
44	14.6	19,472	39	21.6	571
45	13.7	32,727	40	18.5	2,818
46	13.8	32,498	41	19.3	1,707
47	13.8	10,323	42	18.4	3,972
48	14.4	1,569	43	17.4	1,702
49			44	17.0	5,114
50	13.9	1,113	45	17.1	3,414
51	13.3	2,228	46	17.2	3,982
52	13.2	1,668	47	15.7	4,027
53	12.5	2,308	48	15.6	4,553
			49	14.9	2,313
Total.....		114,092	Total.....		36,463

The table and accompanying diagram show clearly that the absorption per cubic foot with both mixed beech and red oak ties falls off as the treating weights of the ties increase. Thus the absorption of red oak at 42 lbs. per cu. ft. is about 14½ lbs. of solution, and at 53 lbs. per cu. ft. about 12½ lbs. For mixed beech the difference is even more marked, varying from about 21 lbs. of solution at 37 lbs. per cu. ft. to 15 lbs. absorption at a treating weight of 49 lbs. per cu. ft.

GULFPORT CREOSOTING COMPANY.

No report submitted.

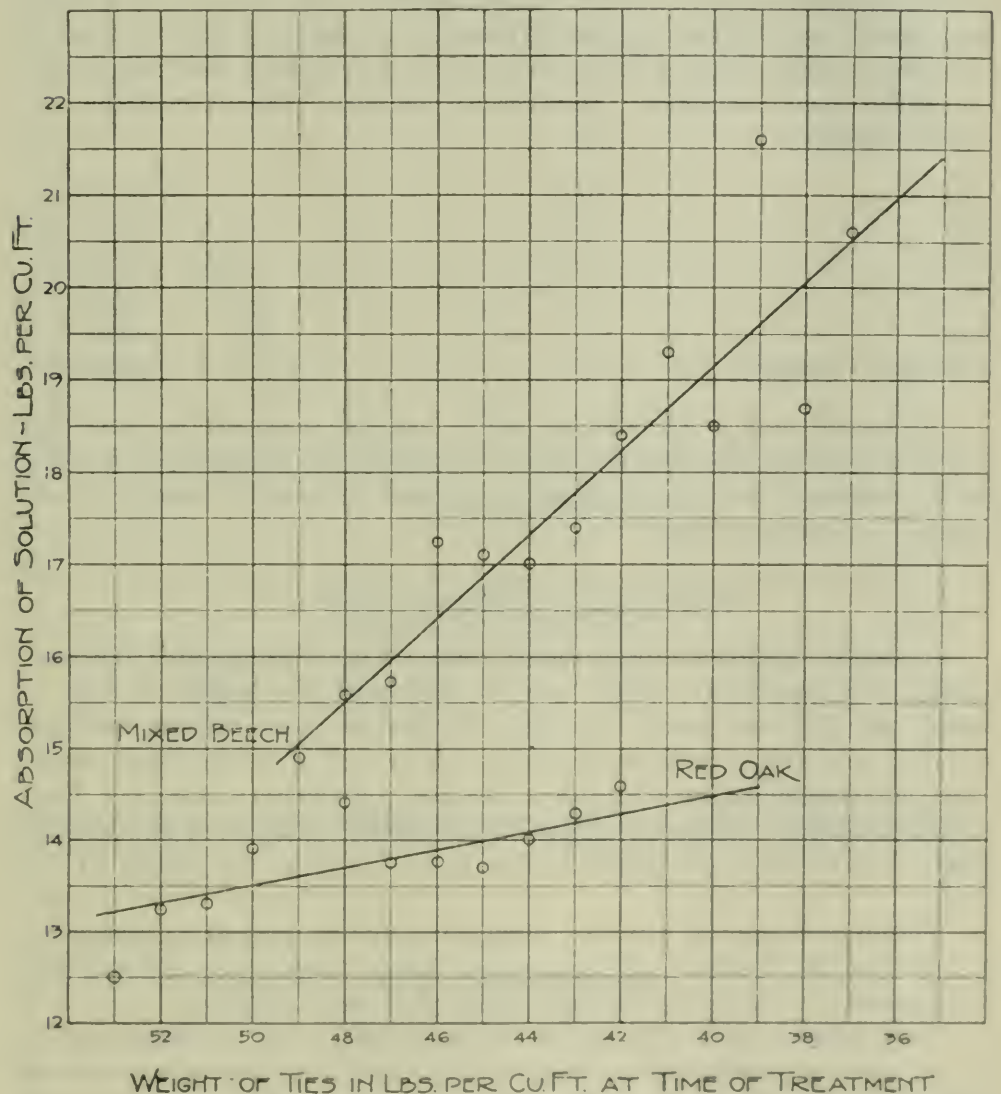
INTERNATIONAL CREOSOTING & CONSTRUCTION COMPANY.

No report submitted.

KETTLE RIVER COMPANY.

Report that they never reached the point of making any actual experiments.

DIAGRAM SHOWING THE ABSORPTION OF RED OAK AND MIXED BEECH TIES AT VARIOUS TREATING WEIGHTS PER CU. FT. CARD PROCESS.



Basis 114,092 Red Oak Ties; 36,463 Mixed Beech Ties.

Treated by the Indiana Zinc-Creosoting Company, Terre Haute, Ind., July, 1909—January, 1910.

NORTHERN PACIFIC RAILWAY.

The report submitted concerns the seasoning and treatment of pine, oak, beech, elm, ash and hemlock crossties at the Paradise, Mont., plant

of the Northern Pacific Railway. The data were compiled by the Forest Products Laboratory.

Two ties of each of the above species, with the exception of the birch and hemlock, of which four ties were used, were piled to air-season in a shed where the air was artificially heated. All were hewn ties 7 in. by 9 in. by 8 ft. and contained an average of sapwood for Minnesota timber. The ties were weighed from time to time to ascertain the rate at which they were seasoning; Fig. 1, in the accompanying diagram, showing graphically the results obtained. After the ties had seasoned to the minimum weight shown in the figure they were placed in the treating cylinder and given a Lowry treatment, all being treated in exactly the same manner. Fig. 2 shows the amount of creosote absorbed by the ties under these conditions. Just before treatment the ties had the following weights:

Pine	110.50 lbs.
Oak	164.25 "
Birch	153.50 "
Elm	135.75 "
Ash	126.00 "
Wisconsin hemlock	168.00 "

Of special note is the rate at which hemlock seasoned, as compared with the other woods, and the large amount of oil absorbed by the ash ties as compared with those cut from oak and hemlock, it being approximately four times as great.

PENNSYLVANIA RAILROAD COMPANY.

At the Mt. Union and Greenwich plants of the Pennsylvania Railroad definite experiments are under way to determine the length of time to season the different species handled, the results from various methods of piling and the period of seasoning which will give the best results from the standpoint of treatment. As the experiments have not been in progress long enough to arrive at a definite solution of the several points, it will only be possible at this time to outline the nature of the work.

The experiments at the two plants are to be identical in character, the tests at Mt. Union to be made with beech, maple and red oak and at Greenwich with beech, red oak, black gum and sap pine.

Two definite lines of experiments are under way. In the first 24 ties of each species are to be weighed and piled 7x1, and at the end of each month two ties of each kind will be weighed and treated. This work was started in April, 1911, but another series will be conducted later to determine the influence of climatic conditions in different seasons of the year. The data eventually produced should indicate the rapidity with which each species seasons and show after what period of seasoning the treatment is most effective.

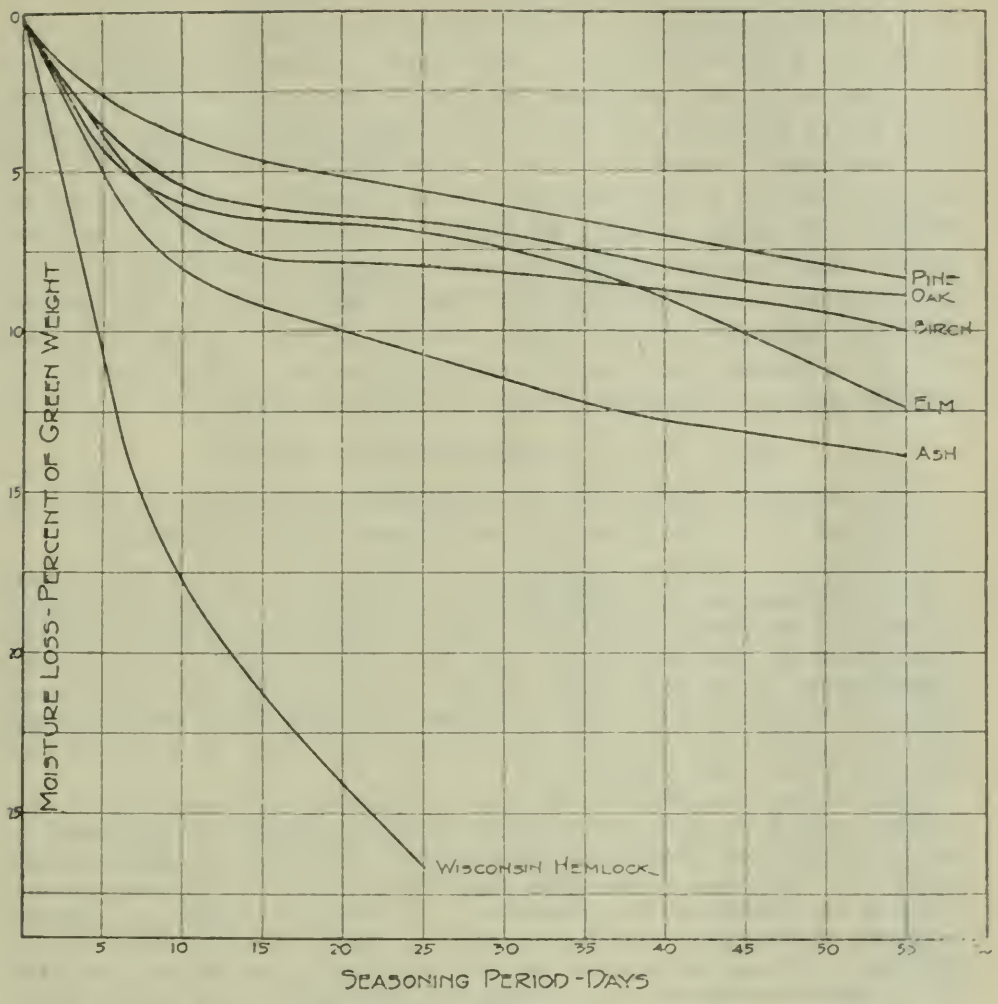


FIG. 1—RATES OF ARTIFICIAL AIR SEASONING OF UNTREATED TIES.

FIG. 2 - ABSORPTION OF CREOSOTE (LOWRY PROCESS) OF AIR SEASONED TIES

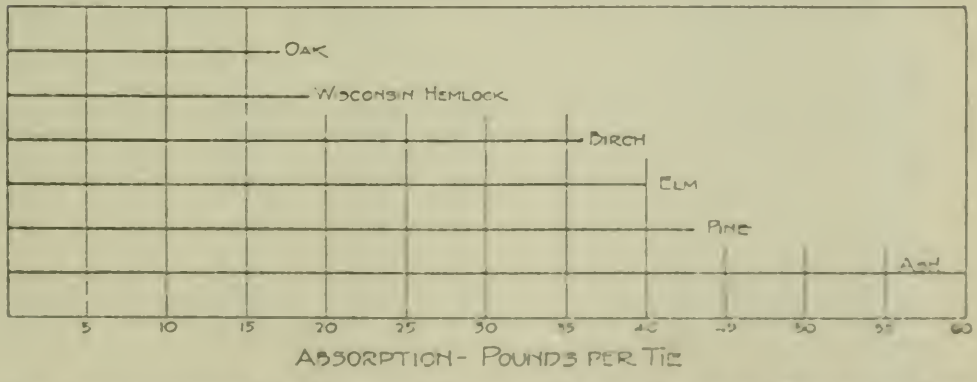


FIG. 2—ABSORPTION OF CREOSOTE (LOWRY PROCESS) OF AIR SEASONED TIES

The second line of experiments will be a comparison of the 7x7 with the 7x1 piling systems, and of open blocks as compared with solid ones. In this test a whole block (six piles square) of oak ties at Mt. Union were piled solid 7x7; adjoining this was a block of ties 7x7, but with 2-foot alleys between each two rows of piles; while another adjoining block was piled according to the Company's present system, with the 7x1 arrangement in the piles, 2-ft. alleys between each two tiers of piles and 4-ft. alleys between the blocks. In each of these experimental blocks a large number of ties has been weighed, marked and placed in various places in the different piles; yet in each block the marked ties will be in approximately the same position. These ties are to be left for 8 or 9 months, and just before treatment the marked ties will be weighed and the comparative rates of seasoning noted.

TEXAS TIE AND LUMBER PRESERVING COMPANY.

This company reports that the grouping and seasoning of pine ties, as described, is in connection with the Rueping empty-cell process.

"We have carried the segregation of pine timber a little further than is customary when we can do so and have tried to separate, when possible, ties that had more than 50 per cent. sapwood from those that had less and treated them in different charges. Our ties at Somerville are also divided approximately 50 per cent. hewn and 50 per cent. sawn, and of our sawn ties we get approximately 65 per cent. heartwood ties with very little sap, and of our hewn ties we get only about 10 per cent. of long-leaf ties, which have very little sapwood on.

"In treating ties with the Rueping process we find, for instance, that we have to put in from ten to fifteen pounds more air in the sawn tie that are 65 per cent. heartwood than we do in the hewn ties that are only 10 per cent. long leaf, with small sapwood to leave in the same amount of oil at the finish of the treatment. We also find when we separate the hewn ties in saps and hearts that we have to make about 15 lbs. difference in the air to leave in the amount of oil when the tie is treated. This is about the extent of our findings on this subject, and it may not be of interest to those not using the Rueping process."

APPENDIX B

RECORD OF SERVICE TESTS

Name of Railroad Co	Information Furnished by	Report No.	Locality of Test	Date Placed	Length of Line in Feet	Number of Pieces	Description of Conditions: Soil	Ballast	Drainage	Rail: Weight	Rail: Plates	Rail: Anchors	Fastenings: Tie Plates	Fastenings: Spikes	Traffic	Description of Material: Specie	Size	Seasoning	Grade	Painted	Treating	Condition before
Baltimore & Ohio	Chief Engr. M of W	1	East of Windsor, Ohio	Feb 1901	2170	1237	Clay	Gravel	Good	90#	C.S.	Spike	Tie Plate	Cut Spike	21800 Tons	Red Oak	Rep 8	Air	Mixed			Heavy
"	"	2	"	"	1600	877	"	"	"	"	"	"	"	"	Per Month	"	"	"	"			and
"	"	3	"	"	2035	1107	"	"	"	"	"	"	"	"		Burn'd Butts	"	"	"			Sawed
"	"	4	"	"	460	250	"	"	"	"	"	"	"	"		"	"	"	"			"
"	"	5	"	"	1860	1011	"	"	"	"	"	"	"	"		Red Oak	"	"	"			"
"	"	6	"	"	1400	760	"	"	"	"	"	"	"	"		White Oak	"	"	"			"
San Nicol & San Antonio	Engr. M of W	1	Between Bay View & Sailes Jct	Oct 1905	9208	1001						Part	Part	Main Line		Pine	7x8		Sap		Thoroughly	Heavy
"	"	2	"	"	6370	1000						Tie	Screw	"		"	"		Heart		Sawed	Unbalanced
"	"	3	"	Mar 1905	5539	1003						Plated	Spike	"		"	7x8-8		Sap		Thoroughly	Heavy
"	"	4	"	"	2800	1000						and	Part	"		Cypress	7x8-8				"	Sawed
"	"	5	"	"	1800	129						Part	Cut	"		Red Gum	6-8				Thoroughly	Sawed
"	"	6	"	"	1625	113						Not	Spike	"		Tupelo	"				"	"
"	"	7	"	"	1419	115								"		Red	"				Not Thoroughly	"
"	"	8	"	"	1204	85								"		Tupelo	"				"	"
"	"	9	"	"	1047	112								"		Red	"				Thoroughly	"
"	"	10	"	"	838	113								"		Tupelo	"				"	"
"	"	11	"	"	678	88								"		Red	"				Not Thoroughly	"
"	"	12	"	"	477	88								"		Tupelo	"				"	"
"	"	13	"	"	314	45								"		Red	"				"	Zinc Creosoted
"	"	14	"	"	231	42								"		Tupelo	"				"	"
"	"	15	Fort Hancock, Texas	Oct 1894		200								"		Pine						
"	"	16	Between Ft Hancock & Sierra Blanca	Jan 1907	804	500		Slag				Tie Plate	Cut Spike	"		Red Oak					Heavily	Diamond Head Process Co
"	"	17	"	"	814	500		"				"	"	"		" Gum					"	"
"	"	18	"	"	816	500		"				"	"	"		Pine					"	"
"	"	19	Between Wharton & Sealy, Tex.	Feb 1907	739	401		Gravel				Tie Plate	Cut Spike	"		"	7x8-8				"	Zinc Creosoted
"	"	20	"	"	399	211		"				"	"	"		"	"				"	Creosoted
"	"	21	"	Apr 1907	172	95		"				"	"	"		"	7x8-8				"	Rueping
"	"	22	Between Lafayette & Scott, Tex.	Jan 1907	162	100		"				"	"	"		"	"				"	"
"	"	23	"	Aug 1906	414	250		"				"	"	"		Red Oak	"				"	Zinc Creosoted
"	"	24	"	Dec 1906	1007	593		"				"	"	"		Pine	7x9-9				"	"
"	"	25	"	"	466	285		"				"	"	"		"	"				"	Creosoted
"	"	26	"	Mar 1907	165	100		"				"	"	"		"	"	Air			"	"
Mex. Central	Mgr Tie & Timber Dept	1	Tampico Branch	June 1905		146								Branch Line		Pine						Rueping
"	"	2	"	"		29								"		"						Gueynemi Creosote
"	"	3	"	"		19								"		"						" Zinc "
"	"	4	"	"		17								"		"						Creosoted
"	"	5	"	"		11								"		"						"
"	"	6	"	"		7								"		Red Oak						Gueynemi Creosote
"	"	7	"	"		43								"		Pine						Burnettized
"	"	8	"	"		10								"		Red Gum						"
"	"	9	"	"		10								"		Pine						Carbolineum
"	"	10	"	June 1907		198								"								Waterfield Crude Oil
New York, New Haven & Hartford	Engr. M of W	1	Bar Haven Tunnel, Conn.	July 1894		6000				100#				Main Line		Pine	7x9		No 1			Zinc Creosote
"	"	2	Danielson Track Tanks, Conn	Oct 1901	600	300								"		"						Burnettized
"	"	3	Wellington, Conn	June 1861		1006								"		White Pine			No 1			Timberry
"	"	4	Medway, Mass.	" 1865										"		Hemlock						Creosoted
"	"	5	Somerset, Mass	" 1888										"		"						"
Norfolk & Southern	Chief Engineer	1	Norfolk Division	May 1897		1095								Main Line		Juniper		Air				
"	"	2	"	"		342								"		Pine		14 months				Vulcanized
"	"	3	"	"		250								"		"		"				Burnettized
"	"	4	"	"		100								"		"		Air				Creosoted
"	"	5	"	"		250								"		Juniper		12 months				Vulcanized
"	"	6	"	"		250								"		Gum		6 "				Burnettized
"	"	7	"	"		300								"		"		6 "				
																White Pine		Air 14 months				
Oregon Washington Railroad & Nav Co	General Manager	1	Dodsons, Oregon	June 1907	749	1000	Loam	Gravel	Good	75#	C 3			Heavy		Douglas Fir	7x9-8	Air	No 1 to No 2	Comm		Sawed
"	"	2	"	"	1885	1006	"	"	"	"	"			"		"	"	"	"	D		"
"	"	3	"	"	1826	977	"	"	"	"	"			"		"	"	"	"	A	Dec 3	"
"	"	4	"	"	1958	1007	"	"	"	"	"			"		"	"	"	Not Specified	C	"	"
"	"	5	"	"	1848	975	"	"	"	"	"			"		"	"	"	"	B	Dec 14	"
"	"	6	"	"	3718	1969	"	"	"	"	"			"		"	"	"	Not Mixed Specified	G	Dec 14	"
"	"	7	"	"	548	300	"	"	"	"	"			"		"	"	"	Not Specified	H	"	"
Peoria Railroad	Chief Engr. Mtl. W	1	Wooster, Ohio	June 1907	12000	2743		Stone		Good	100#	P.S.	Tie Plate	Cut Spike	48000 Tons	Pine	6x8-8	Air	No 1			Sawed
"	"	2	"	"		3850		"		"	"	"	"	"	Per Day	Oak Mixed		"	No 1		Dec 8	Hewn
Southern Pacific	Asst Chief Engr.	1	Yarding		5.67 Miles	663838				Good					Medium	Fir	7x9-8	Air				Sawed

Description of Material: Treating (if any)	Preliminary Vacuum: Inches	Preliminary Vacuum: Time	Pressure: Pounds	Pressure: Time	Temperature: Initial	Temperature: Interval	Preservative Per Cu Ft: Zinc Cl	Preservative Per Cu Ft: Creosote/Mixed	Absorption per Tie: Zinc Cl	Absorption per Tie: Creosote/Mixed	Method of Inspection	Care in Service	Date of Report	Service Records: Average Age	Service Records: Actually Inspected	Service Records: Still in Track: Per Cent	Service Records: Still in Track: Total Service	Service Records: Removed: Per Cent	Service Records: Removed: Total Service
Burnettized	23	1hr 5	179	6hrs 10'	153°	152°	03#	2.0#		55 gals	Annually	On Engr							
Straight Creosoted								0.675gals			or at	M of W							
Zinc Creosoted	23	1hr 0	175	4hrs 50	137°	137°	03#	2.0#		55 gals	Convenient	"							
Straight Creosoted	24	2hrs 5			165°	175°		0.675gals		2.5gals	Periods	"							
Timber Asphalt				Open Steam	210°	2hrs 0			3.996 to 11.09#										
Untreated																			
Burnettized			25	4hrs 0			04.22#			1.44gals	Once	Engineer				38.43			
Untreated											and	M of W				8.10			
Zinc Creosote							0.77#	6.84#		0.835gals	Inside					8.91			
Untreated										2.24gals	& Yard					7.27			
Burnettized							0.738#			0.738gals		"				18.45			
"							0.2399#			0.7995 #						38.03			
"							0.3047#			0.807 #		"				26.08			
"							0.256 #			0.6724 #						7.6			
"								1.252#		3.53 gals						6.18			
"								1.171#		2.982 #						2.22	2.22		
"								1.446#		3.845 #		"	"			2.22	2.22		
"								1.521#		3.915 #						2.22	2.22		
"							0.1738#	0.1289#		2.39 #		6.64 #				2.6 #			
"							0.1239#	0.1999#		2.02 #		5.38 #				7.4			
"																3.82	3.82		
"									0.93 gals							2.22	2.22		
"									0.77 #							2.22	2.22		
"									0.116 #							2.22	2.22		
"								1.96#								2.22	2.22		
"								12#								2.22	2.22		
"																2.22	2.22		
"								12%		4% 12%						2.22	2.22		
"								5.46#								2.22	2.22		
"								12#								2.22	2.22		
																3 yrs	82.00		
												Dept of Tie and Timber Insp				2.22	2.22		

REPORT OF SPECIAL COMMITTEE ON GRADING OF LUMBER.

DR. HERMANN VON SCHRENK, *Chairman;* B. A. WOOD, *Vice-Chairman;*
D. FAIRCHILD. W. H. NORRIS.
R. KOEHLER. F. B. WALKER.
A. J. NEAFIE. C. W. RICHEY.

Committee.

To the Members of the American Railway Engineering Association:

Your Special Committee on Grading of Lumber has not held any formal meetings during the year, the discussions having been carried on by correspondence. The Committee wishes to re-submit the Definitions of Defects and Lumber Grading Rules submitted in its report last year, with certain slight changes, indicated below. The Committee believes that they fairly represent Specifications for Maintenance of Way Lumber as it can be purchased in the market to-day. The rules submitted may not suit all conditions. It is pointed out, however, that the acceptance of these rules by the Association, with a proviso that individual grades can be departed from where the requirements of any particular road seems to make same necessary, will represent a great step forward in bringing about uniform rules for the grading of lumber. It appears to the Committee that slight differences of opinion, concerning one or more grades, should not interfere with the acceptance of these rules in a general way.

The rules as submitted last year have been changed so as to bring them into harmony with those already published in the Manual. The Descriptions and Definitions of Defects are in accord with those already adopted by the Association as standard. There have been added this year Grading Rules for Cypress Lumber.

RECOMMENDATIONS.

Your Committee recommends that the Lumber Grading Rules as presented last year, subject to the corrections and including the additions made below, be adopted as standard.

*Following is a list and reference to the Proceedings where the data included in these recommendations can be found:

(1) Classification and Grading Rules for Douglas Fir (pp. 548-555, Vol. 12, Part 3, Proceedings for 1911).

(2) Specifications for Douglas Fir Structural Timbers. (Substitute for paragraphs 38-51, inclusive, pp. 556, 557, Vol. 12, Part 3, Proceedings, the Specifications for Douglas Fir Bridge and Trestle Timbers, as given on pp. 143 and 144, Manual, 1911. For paragraphs 54 and 55,

*See also Bulletin 133, March, 1911.

page 557, Vol. 12, Part 3, Proceedings, substitute paragraphs 1, 2, 3, 6 and 7, as given on page 145, Manual, 1911).

(3) Classification, Grading and Dressing Rules for Northern Pine, including White and Norway Pine and Hemlock (pp. 565, 577, Vol. 12, Part 3, Proceedings, 1911).

(4) Classification, Grading and Dressing Rules for Southern Yellow Pine (pp. 578-600, Vol. 12, Part 3, Proceedings, 1911). (For paragraphs 43-59, inclusive, substitute paragraphs 1-14, inclusive, as given on pp. 141 and 142, Manual, 1911.)

(5) Standard Specifications for Construction Oak Timbers (pp. 601-606, Vol. 12, Part 3, Proceedings, 1911).

(6) Classification and Grading Rules for Cypress Lumber and Shingles, presented in this report.

Respectfully submitted,

SPECIAL COMMITTEE ON GRADING OF LUMBER.

Appendix E.

CLASSIFICATION AND GRADING RULES FOR CYPRESS LUMBER AND SHINGLES.

GENERAL INSTRUCTIONS.

Cypress lumber shall be graded according to the following rules and specifications, bearing in mind that as no arbitrary set of rules and specifications can be maintained in every case, much must be left to the common-sense and best judgment of the inspector:

1. Lumber shall be manufactured and shipped in standard lengths and thicknesses.

2. Tank, 1st and 2d and worked partition shall be graded from the poorer side.

3. Select lumber, flooring, ceiling, bevel siding and finishing shall be graded from the better or finished side, but the reverse side should in no case be more than one grade lower.

4. All lumber shall be tallied surface or face measure, the tally counted up, and the one-quarter or one-half added to the total where the lumber is one and one-quarter or one and one-half inches thick, and 2 in. and thicker to be multiplied by the thickness.

5. In the measurement of all lumber, fractions exactly on the one-half foot are to be given alternately to the buyer and the seller; the fractions below the one-half foot are to be dropped, and all fractions above the one-half foot are to be counted to the next higher figure on the board rule.

6. In "line boards," pieces 14 ft. and longer shall be given the advantage in grade; pieces 12 ft. and shorter shall be reduced in grade.

7. Recognized defects in cypress are knots, knot holes, shake, splits, wane, worm holes, stained sap and peck.

STANDARD DEFECTS.

8. A standard knot is sound and not to exceed 1¼ in. in diameter.

9. A small sound knot is one not exceeding ¾ in. in diameter.

10. Two small knots not to exceed in extent or damage one 1¼ in. knot.

11. One straight split not to exceed in length the width of the piece.

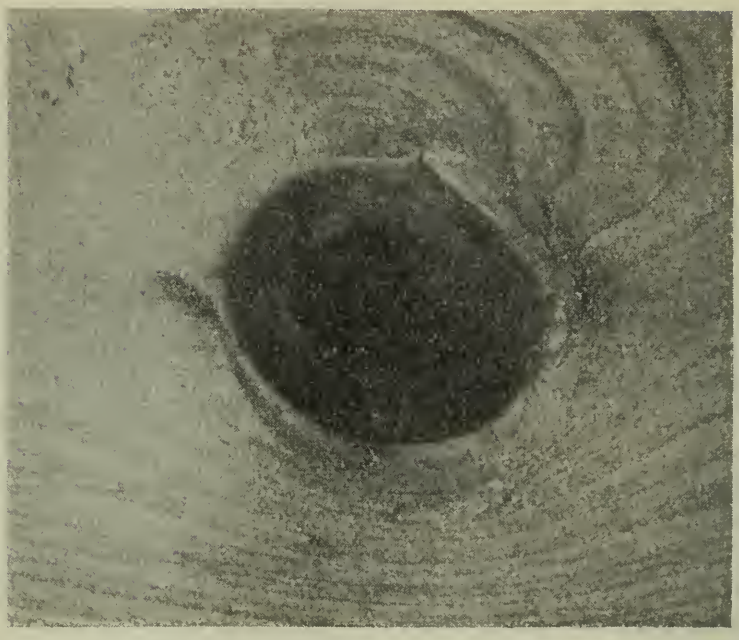
12. Worm, grub, knot and rafting pin holes not exceeding in damage one 1¼ in. knot.

13. Ordinary season checks shall not be considered a defect in any grade.

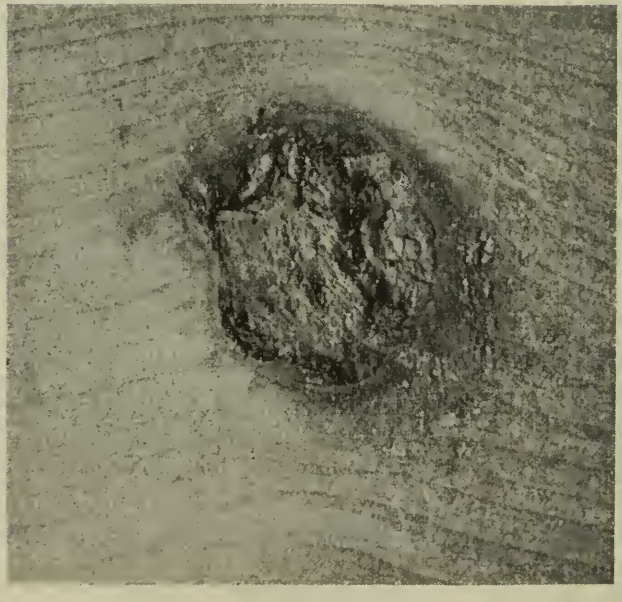
14. Ordinary season checks are such as occur in lumber properly covered on yard, or season checks of equal size in kiln-dried lumber.

15. Bright sap is not a defect in select or below.

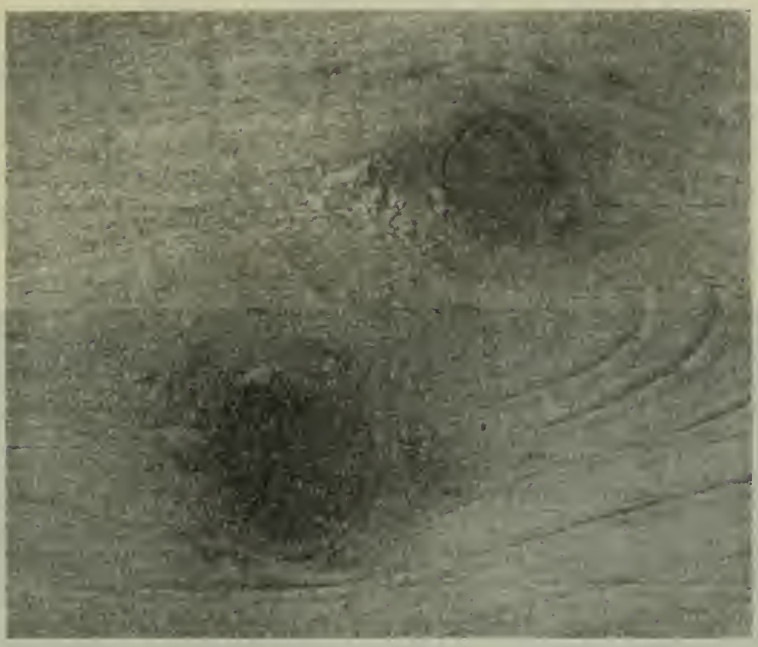
16. Pin worm holes, sound knots and stained sap shall not be considered a defect in No. 1 barn or below.



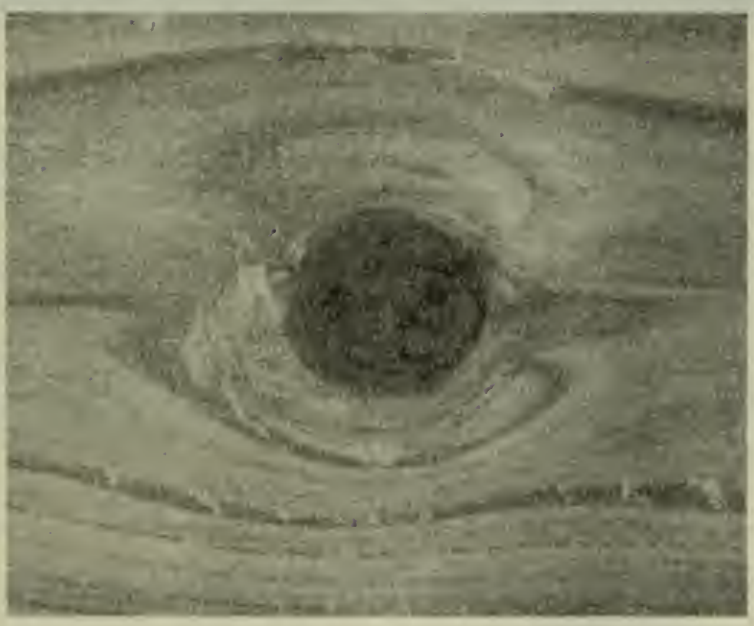
STANDARD SOUND KNOT.



ROTTEN KNOT.



TWO SMALL KNOTS EQUAL TO ONE STANDARD KNOT.



SMALL SOUND KNOT.

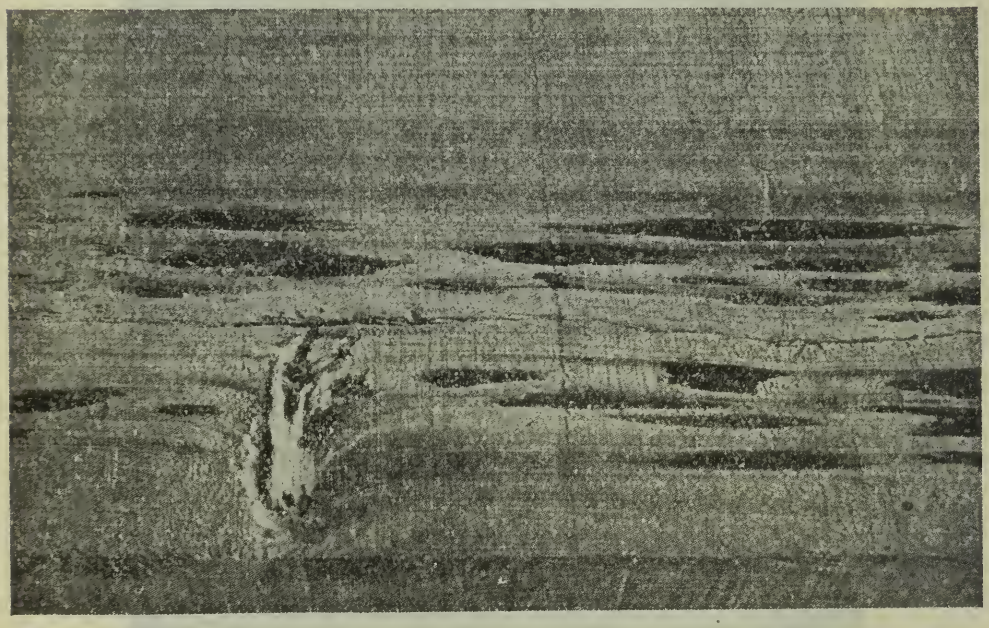
STANDARD LENGTHS.

17. All random standard length stock may be furnished in odd as well as even foot lengths, but there shall not be to exceed 20 per cent. of odd lengths in any one item.

18. Tank stock and No. 1 barn shall be 8 ft. and longer.

19. 1st and 2d and select shall be 10 to 20 ft.

20. Finish, flooring, ceiling, partition, bevel and drop siding shall be 10 to 20 ft.



PECKY CYPRESS.

21. Moldings and battens of all sizes 6 to 20 ft., in both odd and even foot lengths, but not exceeding 10 per cent. of 6, 7, 8 and 9 ft. lengths.

22. No. 2 barn, 6 ft. and longer.

23. Cull or peck, 4 ft. and longer.

STANDARD FINISHED SIZES OF CYPRESS.

24. All lumber shipped in the rough (except 8/4 in. No. 1 and No. 2 "Dimension," which grades may be ¼-in. under or ¼-in. over the size specified, both in thickness and width) shall be of sufficient thickness to S2S to standard thickness, as follows:

25. 4/4 lumber S1S or S2S shall be 13-16 in. thick.

26. 5/4 select, 1st and 2d clear, selected common tank and tank lumber S1S or S2S, shall be 1⅛ in. thick.

27. 5/4 peck, No. 1 and No. 2 barn and finishing lumber S1S or S2S, shall be 1 1-16 in. thick.

28. 6/4 select 1st and 2d clear, selected common tank and tank lumber S1S or S2S, shall be 1⅜ in. thick.

29. 6/4 peck, No. 1 and No. 2 barn and finishing lumber S1S or S2S, shall be 1 5-16 in. thick.

30. 8/4 lumber, except No. 1 and No. 2 barn or dimension S1S or S2S shall be 1¾ in. thick.

31. 8/4 No. 1 and No. 2 barn or dimension S1S or S2S shall be 1⅝ in. thick.

32. 10/4 lumber S1S or S2S shall be 2¼ in. thick.

33. 12/4 lumber S1S or S2S shall be 2¾ in. thick.

34. All lumber S1E takes off ⅜ in. S2E, ½ in.

35. All flooring shall be S2S and C. M.

36. 4/4 flooring shall be 13/16 in. by 2¼ in., 3¼ in., 4¼ in., 5¼ in. face.

37. 5/4 flooring shall be 1 1/16, 6/4 shall be 1 5/16, by same widths as 4/4.

38. ⅜ ceiling shall be worked 5/16 in., S1S only.

39. ½ ceiling shall be worked 7/16 in., S1S only.

40. ⅝ ceiling shall be worked 9/16 in., S1S only.

41. ¾ ceiling shall be worked 11/16 in., S1S only.

42. All widths of ceiling to be the same as flooring, unless otherwise specified. Ceiling up to 3¼ in. face to have one bead on one edge and ceiling wider than 3¼ in. face to be beaded center and edge.

43. Partition to be finished the same as ceiling, but on both faces.

44. Drop siding shall be worked ¾ in. by 3¼ in., 4¼ in., 5¼ in., 7¼ in., 9¼ in. face, S2S and C. M. or shiplapped.

45. Bevel siding or bevel cribbing shall be worked ½ in. less in width than the rough strip measure.

TANK STOCK.

46. This grade shall be random widths, and will not be furnished in specified widths, and shall be graded from the poorer side.

47. This grade shall be 5 in. and wider, 1½ in. to 4 in. thick and 8 ft. and over in length. Pieces up to 7 in. shall be free from sap. Pieces 7 in. to 13 in. may have 1 in. of sound sap on one edge, not to exceed half the length and half the thickness of the piece. Pieces 14 in. and wider may have 1 in. of sound sap on both edges not to exceed half the length and half the thickness of the piece. In all widths sound knots that do not impair usefulness for tank purposes may be admitted.

FIRST AND SECOND CLEAR.

48. This grade shall be random widths, and will not be furnished in specified widths, and shall be graded from the poorer side.

49. This grade shall be 8 in. and wider, 1 in. to 4 in. thick and 10 ft. and over in length. Pieces 8 in. to 10 in. may have 1 in. of bright sap on each edge, or its equivalent on one or both edges, otherwise they must be clear. Pieces 10 in. and under 12 in. may have 1½ in. of bright sap on

each edge or 3 in. on one edge, and may have one standard knot or its equivalent. Pieces 12 in. wide may have 2 in. of bright sap on each edge, or 4 in. on one edge and may have one standard knot; or, in lieu of sap, may have two standard knots or their equivalent. Pieces wider than 12 in. may admit of defects as specified above in proportion as width increases. Pieces 10 in. and wider may admit of one end split, which shall not exceed in length the width of the piece. Pieces 12 in. and less in width, free from other defects, may have bright sap across one face at one end, but this sap shall not exceed in length one-tenth of the length of the piece. In pieces 13 in. and wider bright sap is not a defect.

SELECTS.

50. This grade shall be random widths, and will not be furnished in specified widths, and shall be graded from the better side, but the reverse side shall not be of a lower grade than No. 1 shop or No. 1 barn.

51. This grade shall be 7 in. and wider, but will not be furnished wider than 12 in.; shall be 1 in. to 4 in. thick, 10 ft. and longer. Pieces 10 in. and under in width shall admit two standard knots or their equivalent and an additional standard knot or its equivalent for every 2 in. in width over 10 in. Pieces free from other defects, 10 in. and over in width, to admit pin worm holes on one edge one-tenth the width of the piece. Bright sap is not a defect in this grade. Slight wane on pieces 10 in. and over in width is allowed on one edge not over 3 ft. in length. When no other defect appears, slight amount of stained sap may be allowed. Pieces 10 in. and wider may admit of one end split, which shall not exceed in length the width of the piece.

SELECTED COMMON TANK STOCK.

52. This grade shall be 4 in. wide, or wider, 1½ in. and 2 in. thick, 8 ft. and over in length. Sound sap no defect in this grade, but must be free from unsound knots or other defects that extend through the thickness of the piece, and must be square edged to work the full length of the piece.

NO. 1 BARN OR DIMENSION.

53. This grade shall be specified widths only, shall be 3 in. and wider, 1 in. and thicker, 8 ft. and over in length, admitting sap, bright or stained, shake, season checks, knots, pin worm holes, a small amount of peck on one side and one edge, or very slight peck on both sides and both edges of pieces comparatively free from coarse defects; which defects, however, shall not be sufficient to seriously impair the strength, or prevent the use of each piece for "common" purposes in its full length and full width.

NO. 2 BARN OR DIMENSION.

54. This grade shall be specified widths, 3 in. and wider, 1 in. and thicker, 6 ft. and over in length, admitting all the defects allowed in No. 1

barn, but same may be larger and coarser, and in addition will admit peck on both sides; however, the defects shall not be sufficient to prevent the use of each piece in full length and full width for low-grade fencing and other very common purposes.

CULL OR PECK.

55. This grade may be random or specified widths 3 in. and wider, 1 in. to 4 in. thick, 4 ft. and over in length. Shall admit all pieces below the grade of No. 2 boxing, and shall also admit the product of that part of the log known as "pecky;" however, each piece shall have sufficient strength and nailing surface to permit its use as a low grade boxing, crating, sheating and foundation material.

FINISHING.

56. Shall be specified widths 4 in. and wider, 1 in. to 2 in. thick, 10 ft. and over long, and shall be graded from the better side, A, B and C, but the reverse side should not be more than one grade lower. All grades of finish, rough or S1S or S2S may vary ¼ in. from the width specified.

57. "A" FINISH.—Pieces 4 in. and 5 in. wide shall be clear of sap, knots and other defects. Pieces 6 in. wide may have 1 in. of bright sap, or in lieu of sap one small sound knot. Pieces 7 in. and 8 in. wide may have 2 in. of bright sap, or in lieu of sap one small sound knot. Pieces 9 in. and 10 in. wide may have 3 in. of bright sap, or in lieu of sap two small sound knots, or 1½ in. of bright sap and one small sound knot. Pieces 12 in. wide may have 4 in. of bright sap, or in lieu of sap one standard knot, or two small sound knots, or 2 in. of bright sap and one small sound knot. Pieces 14 in. or wider may have more defects in proportion as the width increases.

58. "B" FINISH.—Pieces 4 in., 5 in. and 6 in. wide may have 2 in. of bright sap and one or two small sound knots, or in lieu of knots may have all bright sap. Pieces 7 in. and 8 in. wide may have 3 in. of bright sap and two small sound knots, or in lieu of knots may have all bright sap. Pieces 9 in. and 10 in. wide may have 4 in. of bright sap and one standard knot or three small sound knots, or in lieu of knots may have all bright sap. Pieces 12 in. wide may have 6 in. of bright sap and one standard or four small sound knots, or in lieu of knots may have all bright sap. This grade will not be furnished wider than 12 in.

59. "C" FINISH.—All widths in this grade shall admit small sound knots, stained sap, pin worms and other defects except shake; but none that will prevent the use of same in its full width and length as a paint grade, and will admit pieces containing one coarse defect which can be removed by making two cuts with a waste of not to exceed 5 per cent. in the one piece removed, but which pieces are otherwise "B" grade or better. This grade will not be furnished wider than 12 in.

60. "D" FINISH.—All widths will admit sound knots, stained sap, pin worms, slight shakes, and other defects; but none that will prevent the use

of same in its full width and length as a common paint grade. This grade will not be furnished wider than 12 in.

SIDING.

61. Siding shall be 4 in. and 6 in. in width, 10 ft. to 20 ft. in length, and graded from the finished side, A, B, C and D.

62. "A" SIDING.—May have 1 in. of bright sap on thin edge, and may contain one small sound knot.

63. "B" SIDING.—May have any amount of bright sap, or if not all bright sap, may have three small sound knots, shake, split or pin worm holes not exceeding in damage the three small knots as above, and may have slight wane on the thin edge. In the absence of other defects a small amount of stained sap will be permitted.

64. "C" SIDING.—May have one to five knots, the whole not aggregating over 3 in. in diameter, or knots, splits or other defects that can be removed in two cuts with waste not exceeding 10 per cent. of the length, or may have small amount of stained sap and pin worm holes not exceeding in damage the five small knots above described.

65. "D" SIDING.—May have stained sap and pin worm holes, or may have other defects that will not cause a waste to exceed one-third the piece.

FLOORING AND CEILING.

66. Shall be specified widths, 10 ft. to 20 ft. in length and graded from the finished side, or if both sides are finished, it shall be graded from the better side, A, B, C and D.

67. "A"—May have bright sap on one edge one-fourth its width, otherwise must be clear.

68. "B"—May have one-half of its face bright sap if otherwise clear, or in lieu of sap, may contain two small sound knots, or may have a split not to exceed 9 in. at one end.

69. "C" (10 to 20 ft.)—May have all bright sap, or may have one to five knots, the whole not aggregating over 3 in., or knots or other defects that can be removed in two cuts with waste not exceeding 10 per cent. of the length, or may have three pin worm holes, or may have check or split at one end, not to exceed 10 per cent. of the length.

70. "C" (4 to 9 ft.)—May have all bright sap, small sound knots, stained sap, pin worm holes and other defects except shake, but none that will prevent the use of each piece the full length.

71. "D"—May have stained sap and pin worm holes, or may have unsound knots or other defects that will not cause a waste to exceed one-third the piece.

PARTITION.

72. Shall be same widths and lengths as flooring and ceiling, but shall be graded from the poorer side, A, B, C and D, same grading to apply as in flooring and ceiling.

PICKETS.

73. Shall be graded No. 1 and No. 2.

74. 1 in. by 1 in. shall be Headed and S4S to 13-16 in. by 13-16 in.

75. 1¼ in. by 1¼ in., shall be Headed and S4S to 1 1-16 in. by 1 1-16 in.

76. 1½ in. by 1½ in. shall be Headed and S4S to 1 5-16 in. by 1 5-16 in.

77. 1 in. by 3 in. shall be Headed and S4S to ¾ in. by 2½ in.

78. No. 1.—Shall be well manufactured, bright sap, no defect and may contain one small sound knot.

79. No. 2.—Shall admit stained sap, sound knots, pin worm holes, slight shake, and pickets thrown out of the No. 1 grade because of poor manufacture.

BATTENS.

80. Battens, both flat and O. G., are not moldings. Same are invariably used with "common" lumber and shall, therefore, be graded No. 1 barn and better, admitting all defects allowed in No. 1 barn, but none that will prevent the use of each piece in full length for Batten purposes. ⅜ in. Battens shall be 1 in. strips S2S to 13-16 in. by 2½ in. and resawed, or 1 in. by 2¾ in. to 3 in. S2S and resawed. Unless otherwise specified, ⅜ in. or flat battens shall be S2S only and resawed.

81. O. G. Battens shall be manufactured in the sizes and pattern shown in the Universal Molding Book.

CAR ROOFING AND SIDING.

82. "C AND BETTER" GRADE.—This grade will admit sound knots, stained sap, pin worm holes, very slight shake and other defects, but none that will prevent the use of each piece in its full width and length for car roofing and car siding; may be random or specified lengths and may be worked to pattern specified and graded from pattern side or S2S and C M and graded from the better side.

CAR LINING.

83. Shall be specified widths and 8 to 20 ft. in length. Will admit tight knots, stained sap, pin worm holes, slight shake and other defects, but none that will prevent the use of each piece in its full width and length for car-lining purposes.

SHINGLES.

84. BESTS.—A dimension shingle, 4, 5 and 6 in. in width, 16 in. long, each width packed separately, 5 butts to measure, 2 in., to be all heart and free of shake, knots and other defects.

85. PRIMES.—A dimension shingle, 4, 5 and 6 in. in width, 16 in. long, each width packed separately, 5 butts to measure 2 in., admitting tight knots and sap, but free of shake and other defects, but with no knots within 8 in. of the butts.

86. This grade may contain shingles clipped two-thirds of the width and one-eighth of the length on the point.

87. STAR A STAR.—A random width shingle 3 in. and wider, 14 in. to 16 in. long, otherwise the same as primes.

88. ECONOMY.—Dimensions 4, 5 and 6 in., each width separately bunched, admitting sap and sound knots, may have slight peck 5 in. from butts, imperfections on points no objection and admitting 14 in. shingles.

89. CLIPPERS.—All shingles below the above grades which are sound for 5 in. from the butts, worm holes and slight peck excepted, random widths 2½ in. and wider.

90. The count of our manufacture of shingles, of all grades, is based on 4,000 linear inches in width, making 1,000 standard shingles, consequently there would be only 667 6-in. shingles packed and counted as 1,000 standard shingles; 5 in. dimension being counted in like proportion.

91. In making re-inspections of shingles, one bundle out of 20 bundles taken at random, shall be cut open, the results of this investigation to form the basis of arriving at the grade of the entire shipment.

REPORT OF COMMITTEE VI—ON BUILDINGS.

MAURICE COBURN, *Chairman;*	M. A. LONG, *Vice-Chairman;*
G. W. ANDREWS.	A. T. HAWK.
W. G. ARN.	N. H. LAFOUNTAIN.
J. P. CANTY.	E. N. LAYFIELD.
O. P. CHAMBERLAIN.	H. A. LLOYD.
D. R. COLLIN.	JOHN S. METCALF.
C. G. DELO.	J. W. ORROCK.
W. T. DORRANCE.	W. F. SCHULTZ.
C. H. FAKE.	W. S. THOMPSON.

Committee.

To the Members of the American Railway Engineering Association:

Your Committee on Buildings has held several meetings during the year at Chicago, Pittsburg and Buffalo, besides various meetings of sub-committees.

The following subjects were assigned the Committee by the Board of Direction:

(1) Report on the advantages and disadvantages of various types of freight house floor construction.

(2) Continue the study of roof coverings.

(3) Present principles covering the design of inbound and outbound freight houses.

(4) Continue the study of concrete coaling stations.

The Committee reports progress on subject (1) Report on the advantages and disadvantages of various types of freight house floor construction.

No recommendations are made as to revision of the Manual.

ROOF COVERINGS.

The Committee presents as information some miscellaneous corrections and additions to last year's report on roofing. As yet the report is incomplete.

The Committee had hoped this year to present specifications for coal-tar pitch, but we were unable to offer sufficient inducements to extract the necessary information.

Page numbers refer to the annual report in Vol. 12, Part 1.

Page 589, last paragraph: A single asphalt fluxed by a single oil is ordinarily an imperfect and unsatisfactory roofing material. Like a cut back tar pitch, it lacks stability. The oil is liable to separate out, sometimes supposedly by capillary attraction into the felt, leaving a brittle compound. The successful asphaltic roofing compounds are ordinarily composed of several different materials.

Page 590, last paragraph: Elaterite occurs in Utah in territory near where gilsonite is found, and has much the same appearance, but is found only in narrow veins. Its qualities are considerably different from those of gilsonite, said to be in part due to the presence of considerable sulphur. From it is made a high-priced product which is supposed to be especially valuable as a constitutent of the protective coating of ready roofs. We are of the opinion that some products advertising elaterite contain it in only small quantities, if at all.

Page 591, paragraph 2: Rock Asphalt or Mastic Rock.—There is also bitumen saturated limestone of which that found in Uvalde County, Texas, is an example.

Page 591, last paragraph: The first two sentences should be changed to read as follows: "Eastern oils are largely made up of compounds of the paraffine series, which vary in consistency from comparatively thin oil to hard scale paraffine."

There are other members of the paraffine series which are light gases.

Page 592, paragraph 1: The method of distillation of California oils profoundly modifies the character of the residual.

Page 592, paragraph 2: The blown oils are coming to be more appreciated. They can be made into a very uniform product of great value for many purposes, and now that certain patents covering them are expired, their use will probably broaden considerably.

Page 592, paragraph 4: The bitumen in the coal-tar includes, besides the hydrocarbons, other organic compounds, which are, however, present in roofing pitch only in small quantities.

Page 593, last paragraph: Water Gas Tars.—In making carburetted water gas, the procedure is as follows: Steam is blown through a bed of incandescent coal or coke, where it is broken up, forming blue water gas, which consists of about equal quantities of hydrogen and carbon monoxide. This gas, which has no illuminating value, is passed into a second chamber, which is filled with checker brick and which has been previously raised to a high temperature. Into this chamber is sprayed petroleum oil, which, by the intense heat, is broken down into permanent gas and a tar consisting, in the main, of aromatic hydrocarbons similar to those occurring in coal-tar. This permanent gas is of high illuminating value and imparts its luminosity to the blue water gas, while the tars drop out further on in the process of manufacture. It is from this tar that water gas tar pitch and other products are obtained.

Water gas tar contains some free carbon, but usually not over 2 per cent. Its pitch is not acted upon by water. There is a very general opinion among practical roofing men that the water gas tar products are less stable than the coal tar pitches, but we cannot find that there has been any accurate proof of this. Its small percentage of free carbon materially interferes with its value as a roofing pitch. It is said that carbon can be added, but we doubt the commercial practicability of such a scheme.

Page 596, paragraph 6: Burlap decays much more readily than the average cotton felt.

Page 597, last paragraph: To combat severe conditions encountered like those at locomotive engine houses, instead of the dry sheet, an asphalt or oil-saturated felt is sometimes used. This does not so readily deteriorate. One roofer uses for this purpose asphalt asbestos sheets, which are perhaps better yet.

Page 600, last paragraph: General specifications for an asphalt built-up roof cannot well be prepared because of the differences in materials, and ordinarily must come from the manufacturers of the materials.

The successful laying of an asphalt built-up roof in cold weather is a difficult matter. If the asphalt is hot enough to be properly handled, there is chance of charring the felts. On steep slopes thorough mopping is difficult and there is chance of danger to the men. One of the chief reasons for deterioration of the asphalt is supposed to be gradual absorption, due to capillary action of the flux into the felt.

Page 601, second paragraph: Asbestos Asphalt Built-Up Roofings.—It is claimed that asbestos felt, acting as it does more as a protection to the layers of waterproofing material and not merely as a medium for carrying them, does not have any capillary action on the oil fluxes, and that the bitumen is so protected that it retains its elasticity and waterproofing qualities much longer than with the other types of felt. If this point is sustained, asbestos felts have a superiority for asphalt roofing over the ordinary felts which may more than overbalance the increased costs. While the experience obtained from this material is not nearly as extended as that which has been had from rag felts, these roofings have been in use for about eleven years, and we have so far found nothing to disprove this claim.

The asbestos felt has advantage due to its freedom from action by fire and decay, and it is claimed that the asbestos roofings have a considerable value in their blanketing influence on fires inside the building covered, which the ordinary felts do not have, points the value of which we consider have been overemphasized. The asbestos felt is not in any danger of being charred by hot asphalt which sometimes happens with rag felts.

The asbestos built up roofings also avoid the gravel or slag necessary with the ordinary "wool" felt built-up roofing. This freedom from the use of gravel or slag with its tendency to roll or be washed off the roof into the gutters would seem to be of some advantage. This also makes it easier to locate a leak and leaves the asbestos roofings much lighter in weight than the other types, an advantage which is probably to some extent offset by the insulating power of the much greater amounts of material used with the "wool" felt. As with all built-up asphalt roofings, difficulties encountered in the mopping make a slope of not more than three inches to the foot desirable.

Tar has not been successfully used with asbestos felts.

As compared with a five-ply tar and gravel roof a four-ply asbestos roof will ordinarily cost at least from one to two dollars more a square.

A three-ply roof is supposed to give good results over concrete, but for wood sheathing it would seem to be approaching too closely to the conditions met with in ready roofing, for first-class work.

Page 609, paragraph 2: Concrete Roofings.—The Asbestos-Portland cement shingles seem to be gaining ground. The different manufacturers use different methods and the results obtained must be used with caution, as it is claimed that the methods of manufacture have an important bearing on the results which may be expected. Shingles of this type are said to have been successfully used abroad for many years. Recent changes are said to have much improved the quality of the material.

For small buildings, or where the design is such as to make tile undesirable, they have especial advantages. The growing difficulty of obtaining good slate should tend to increase their sale. Their cost is somewhat greater than good slate, but their uniformity is such that they can more successfully be laid French or diagonal method than can slate. A considerable saving can be made by laying them French method, but we do not consider this good practice especially with large sheets (see diagram). The material is somewhat brittle and with this method considerably greater amounts of breakage are to be expected, especially on the points.

When new, some water may be absorbed, but as they grow older this defect tends to disappear.

The corrugated sheets should have value as a substitute for corrugated iron sheets. They must be laid with good fastenings and sufficient lap to insure against leakage. They must not be nailed. Some of these materials are strengthened by wire mesh and some with perforated steel sheets grading toward the metal protected by asphalt and asbestos.

Gutters.

Gutters for many classes of railway buildings may and should be omitted. This is more particularly true of buildings with steep roofs near tracks where cinders from passing locomotives roll down the roof into the gutters and in time, unless more care is taken to keep them clean than is usual in railway buildings, the downspouts become choked and fail to carry off the water.

Gutters may be of metal, wood, or be formed in roof of the materials used in the construction of the roof, the latter being ordinarily preferable where the design of the building permits.

Wood gutters are usually of Ogee form on the outside and owing to the thickness of shell the capacity is small for the size of the gutters. They are made in three sizes, 3x4, 4x5 and 4x6. The capacity of these sizes is, however, scarcely more than one-fourth the same size of metal gutters of equal outside dimensions. They are the most durable kind of gutters for buildings exposed to smoke and cinders. They are usually made of fir, white pine or cypress and should be painted inside and out every few years.

Metal gutters are made of copper, galvanized steel, iron, tin or zinc. For permanent buildings, copper is preferable. All joints should be sol-

dered and riveted with not less than four rivets for smaller sizes and should be well braced at least every four feet and proportionately increased in number for larger sizes. The common grades of galvanized steel often used cannot be depended on for more than two or three years. Some of the refined irons now on the market should be of value for this purpose. Cast-iron gutters are used to a limited extent.

Gutters may be built in the roof, or hanging, as the design of the building requires. Hanging gutters, which are easier to repair, and which do not damage the building if defective, are generally preferable. They should be given as much slope as practicable to the various downspouts and the outer edge of hanging gutters should be low enough to avoid chance of damage by possible backing up of water due to stopped-up gutters and conductor pipes.

Copper gutters should be given a coat of linseed oil and tin gutters a coat of iron oxide paint soon after hanging, and galvanized iron should not be painted until about a year of exposure to the weather unless a special acid treatment is applied to provide a surface which will hold the paint. If a galvanized iron roof is used where copper gutters are applied, care should be taken to insulate or separate the two metals so that galvanic action will be prevented.

FLASHINGS.

The following definitions, together with the diagrams, are presented as information concerning flashings. The numbers accompanying the different diagrams refer to the numbers of the definitions.

(1) Flashings are the mechanical unions between roof surfaces and other parts of the structure intersecting and bounding the plane of the roof, and between roofs in different planes.

(2) Vertical Flashings are flashings between roofs and other parts of the structure which intersect the plane of the roof and extend through or above the roof. (Examples: Walls, parapets, combings, soil pipes.)

(3) Lateral Flashings are flashings between roofs and other parts of the structure which bound the roof or which intersect the plane of the roof without extending above it, or, flashings between roofs in different planes. (Examples: Cornices, eaves, gutters, leader heads, ridges, hips, valleys.)

(4) Head Flashings are flashings which are approximately at right angles to the general slope of the roof, at the top of the incline.

(5) Side Flashings are flashings which are approximately parallel to the general slope of the roof.

(6) Foot Flashings are flashings which are approximately at right angles to the general slope of the roof, at the foot of the incline

(7) Expansion Flashings are flashings built of two independent parts, each of which is respectively an integral part of the roof, and of the adjoining structure.

(8) Base Flashing is that part of an expansion flashing which is an integral part of the roof.

(9) Cap or Counter Flashing is that part of an expansion flashing which is an integral part of the adjoining structure.

(10) Continuous Flashings are flashings which are integral parts of both roof and adjoining structure, without slip or expansion joint.

(11) Protective Flashing is that part of a continuous flashing which is an integral part of the adjoining structure, but which does not form an expansion joint with a base flashing.

(12) Homogeneous Flashings are flashings built of the same materials as the roof.

(13) Mixed Flashings are flashings formed of materials other than materials of the roof. (Examples: A metal base flashing for a felt roof.)

(14) Natural or Structural Flashings are flashings which are formed structurally integral with the roof or adjoining structure. (Example: A cap flashing built into a raglet in a parapet wall.)

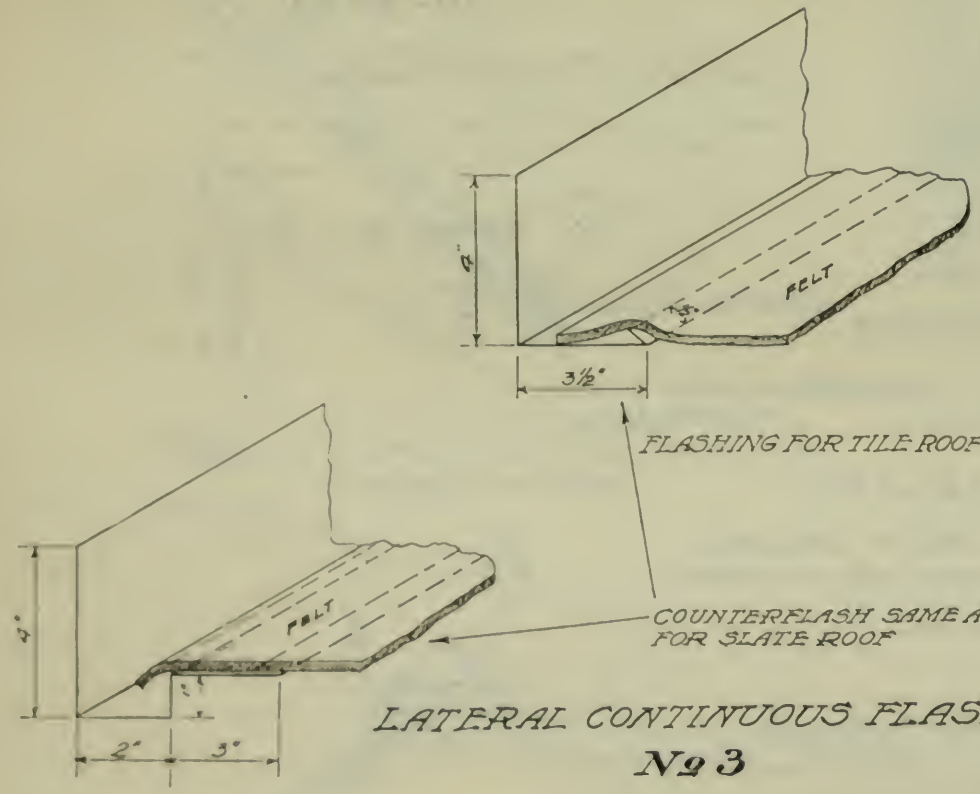
(15) Artifical Flashings are flashings which are not structurally integral with either the roof or the adjoining structure. (Example: A "base" or "continuous" flashing supported upon the adjoining structure by adhesion of materials, or outside cleats.)

The accompanying diagrams are designed to be only illustrative of the distinctions defined above. No effort has been made to formulate recommendations for details of applications of different materials under different conditions.

The report has been signed by Maurice Coburn, M. A. Long, G. W. Andrews, J. P. Canty, O. P. Chamberlain, D. R. Collin, C. G. Delo, W. T. Dorrance, C. H. Fake, C. F. W. Felt, A. T. Hawk, E. N. Layfield, W. G. Arn.

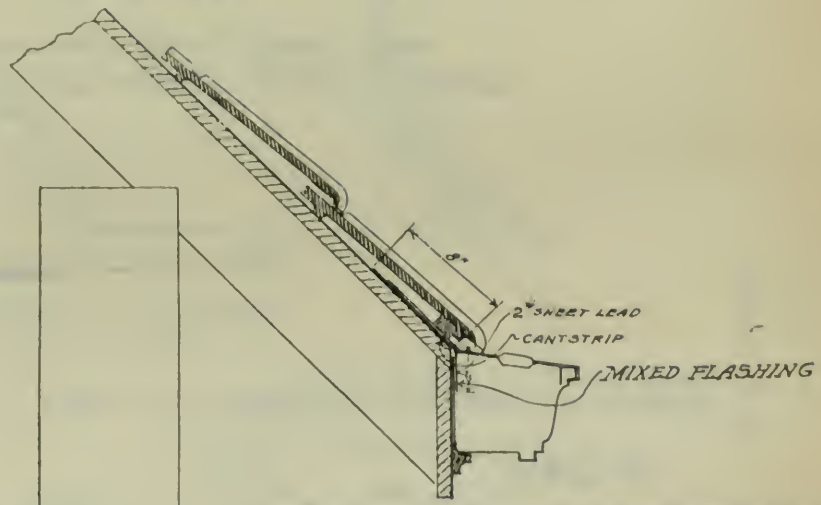
Respectfully submitted,

COMMITTEE ON BUILDINGS.



LATERAL CONTINUOUS FLASHING.

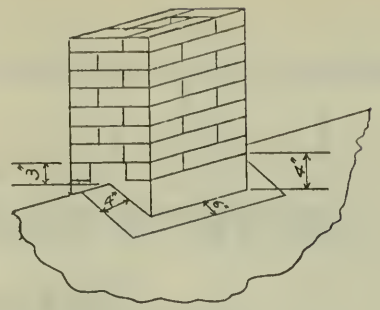
№ 3



LATERAL CONTINUOUS FOOT FLASHING
SECTION THROUGH CORNICE,
SHOWING CANT STRIP AND GUTTER METAL
UNDER TILE.

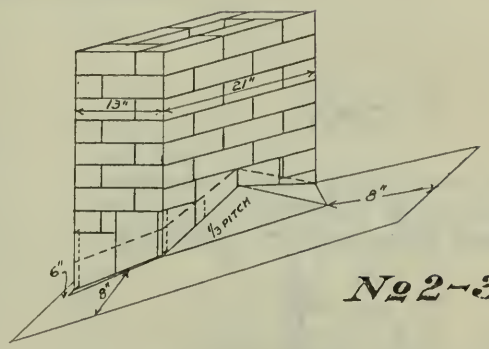
№ 3

Details of Flashing and Counter Flashing for Roofs and Walls.



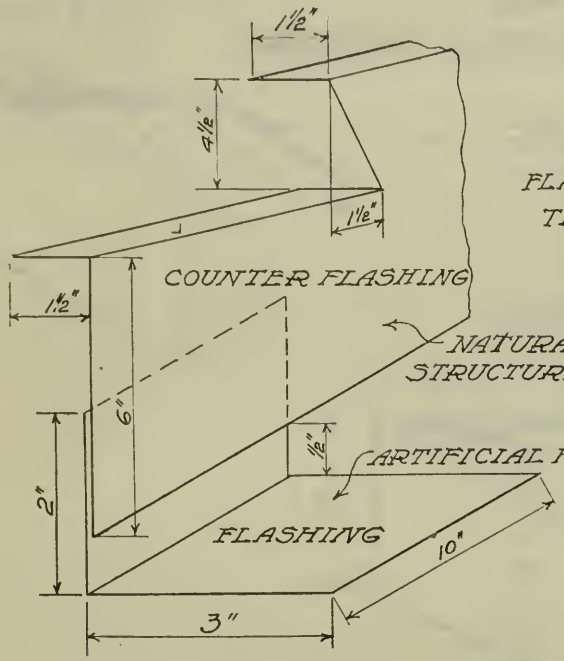
FLASHING FOR CHIMNEY THROUGH RIDGE

№ 2–3



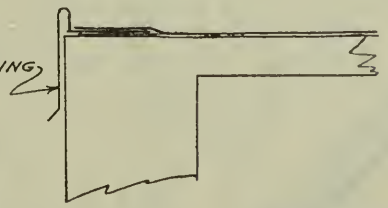
№ 2–3

SADDLE FOR CHIMNEY THROUGH SLOPE OF ROOF



FLASHING AND COUNTER FLASHING FOR SLATE ROOF.

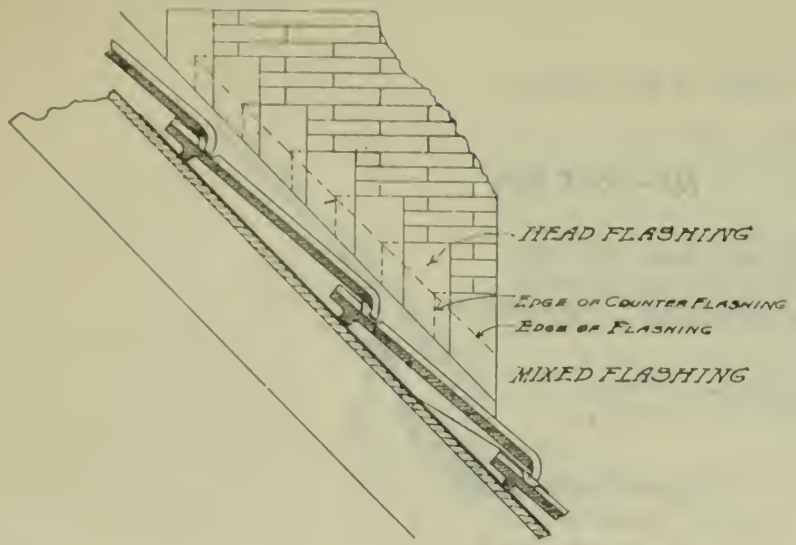
№ 14–15



LATERAL CONTINUOUS SIDE FLASHING.
FLUSH DECK AND SIDE FLASHING.

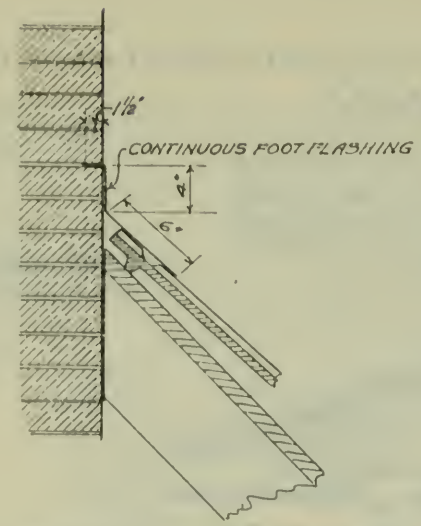
№ 5–13

DETAILS OF FLASHING AND COUNTER FLASHING FOR ROOFS AND WALLS.



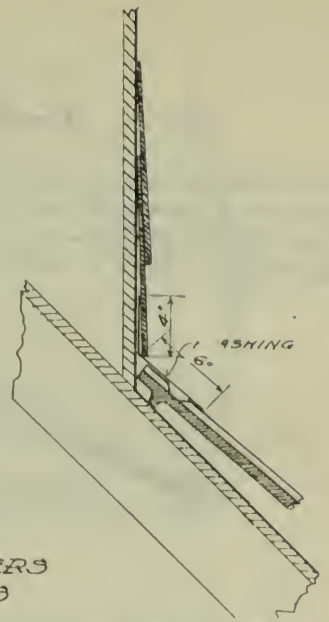
FLASHING AGAINST PERPENDICULAR WALLS
FOR INTERLOCKING AND SPANISH TILES

№ 4



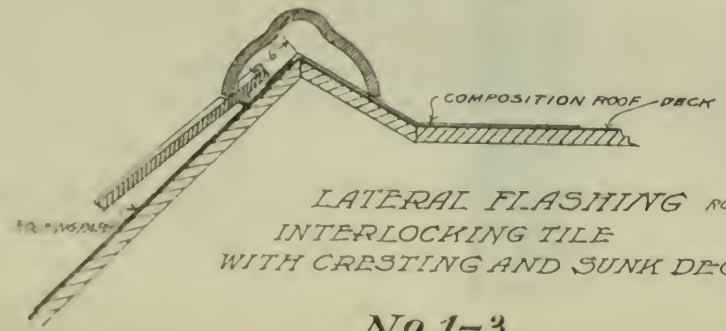
FLASHING AT BASE OF DORMERS
AND AGAINST BRICK WALLS

№ 2–10



CONTINUOUS FLASHING.
FLASHING AT BASE OF DORMERS
IN CONNECTION WITH SIDING TILE

№ 2–10



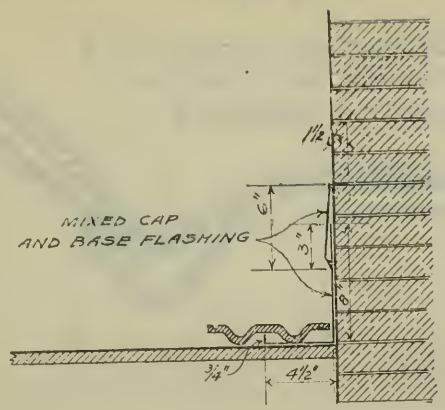
LATERAL FLASHING
INTERLOCKING TILE
WITH CRESTING AND SUNK DECK

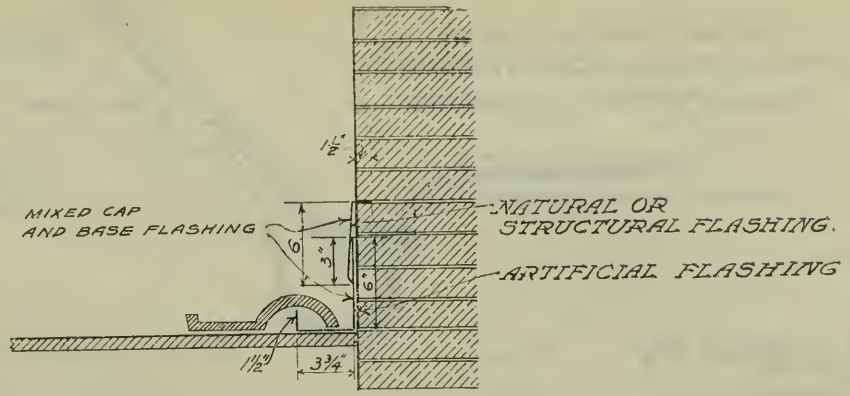
№ 1–3

LATERAL FLASHING.
SPANISH TILE WITH CRESTING
AND SUNK DECK

№ 1–3

DETAILS OF FLASHING AND COUNTER FLASHING FOR ROOFS AND WALLS.



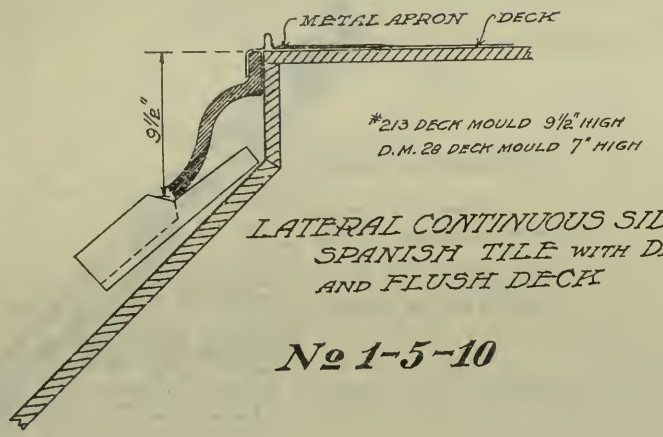


VERTICAL EXPANSION SIDE FLASHING

FLASHING AGAINST PERPENDICULAR WALLS FOR INTERLOCKING TILES.

FLASHING AGAINST PERPENDICULAR WALLS FOR SPANISH TILE

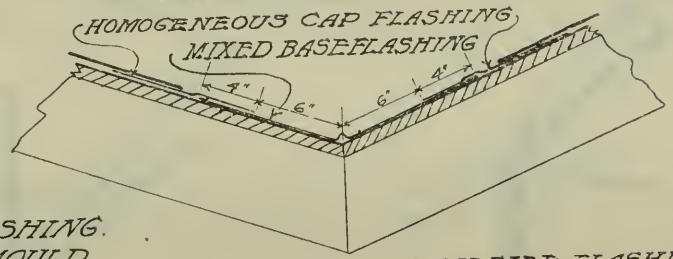
№ 2-7-9



LATERAL CONTINUOUS SIDE FLASHING.
SPANISH TILE WITH DECK MOULD AND FLUSH DECK

№ 1-5-10

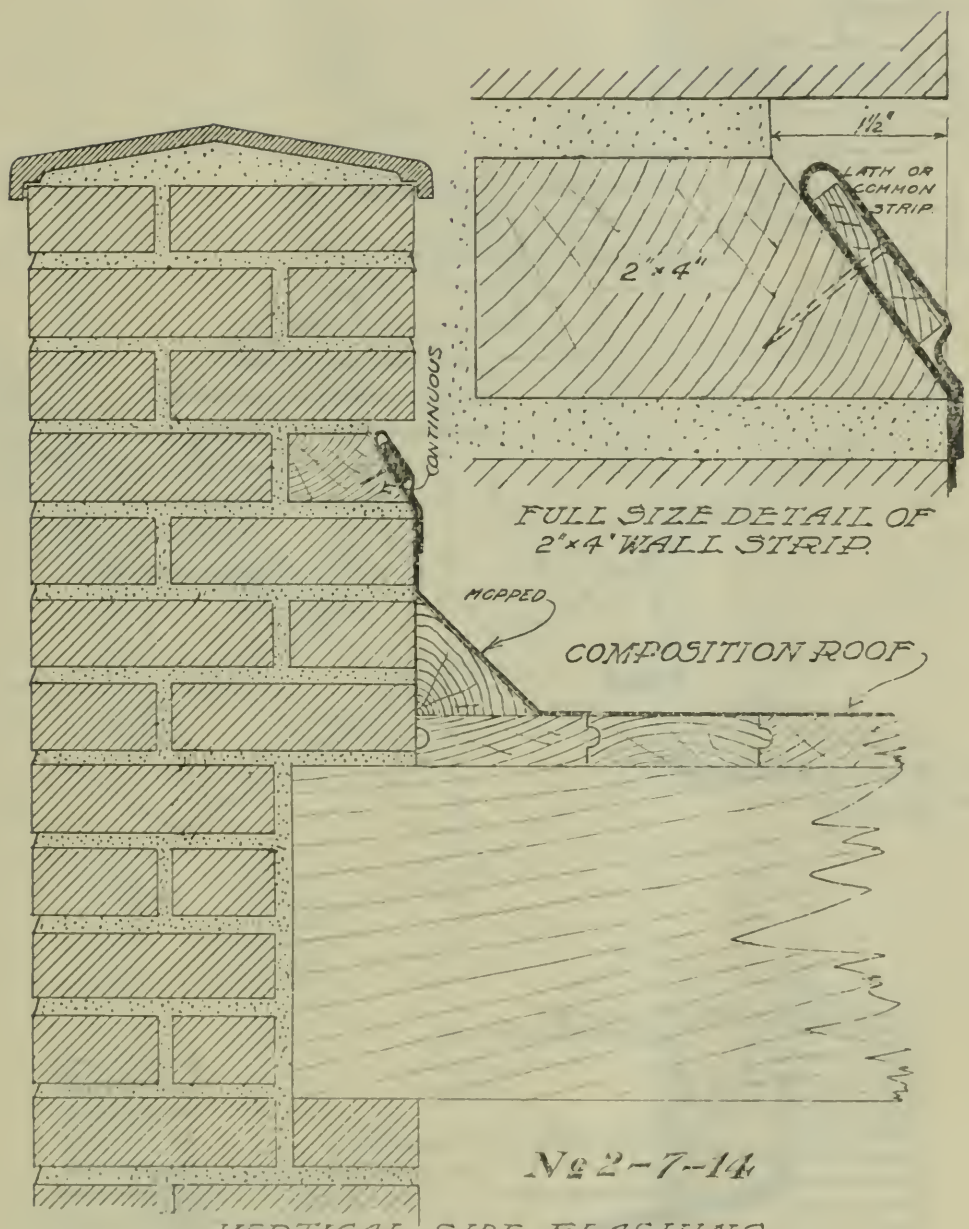
№ 2-7-9



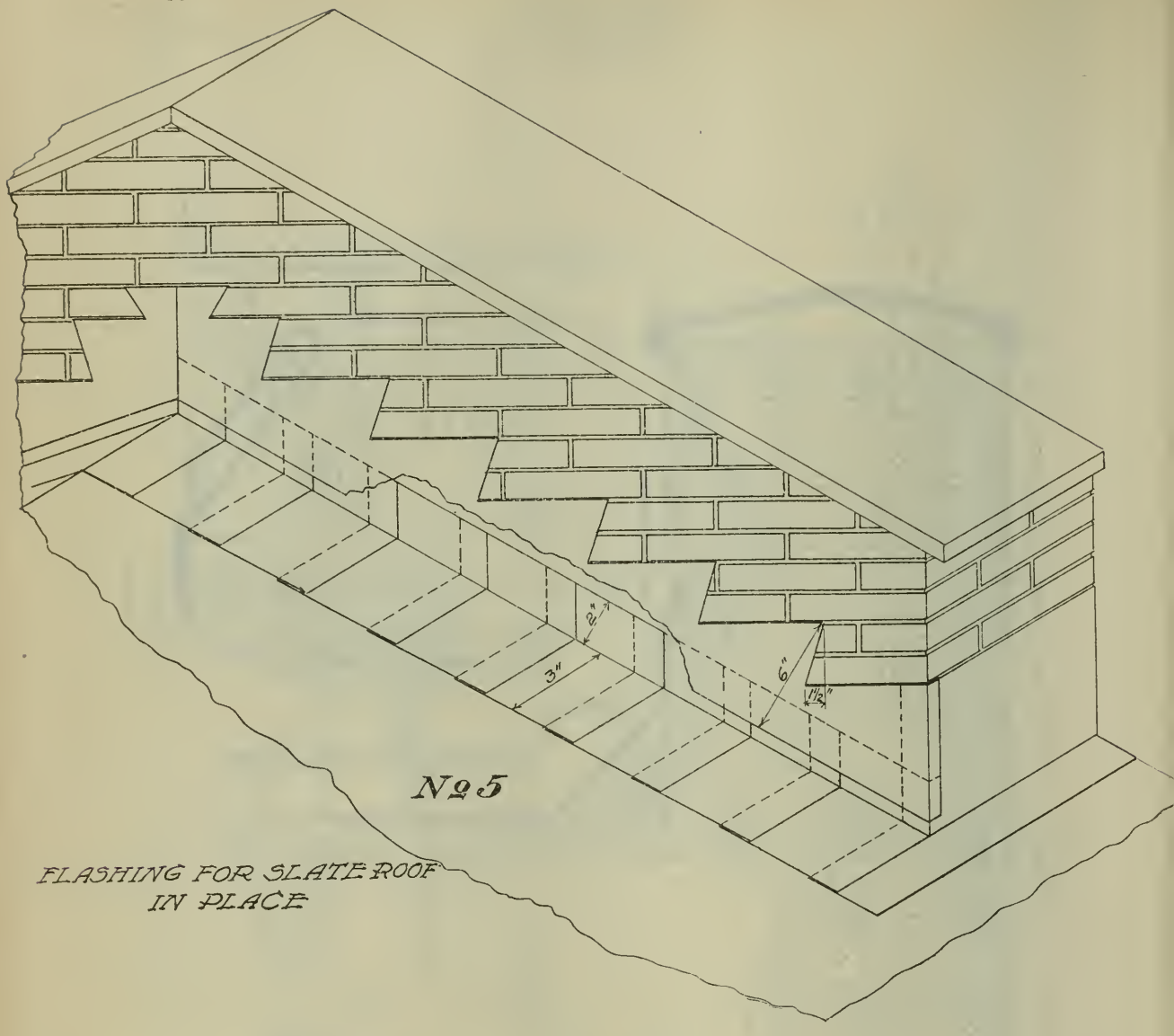
LATERAL EXPANSION SIDE FLASHING.
SHOWING VALLEY METAL MINIMUM WIDTH.
WIDTH OF METAL VARIES WITH LENGTH OF VALLEY AND DISCHARGE OF WATER.

№ 1-3-10

DETAILS OF FLASHING AND COUNTER FLASHING FOR ROOFS AND WALLS.

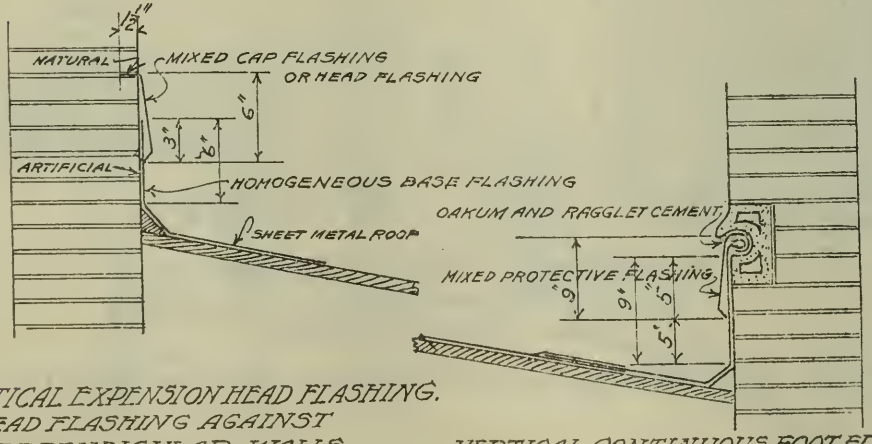


Details of Flashing and Counter Flashing for Roofs and Walls.



№ 5

FLASHING FOR SLATE ROOF
IN PLACE



VERTICAL EXPENSION HEAD FLASHING.
HEAD FLASHING AGAINST
PERPENDICULAR WALLS

№ 2-4-7-9-12

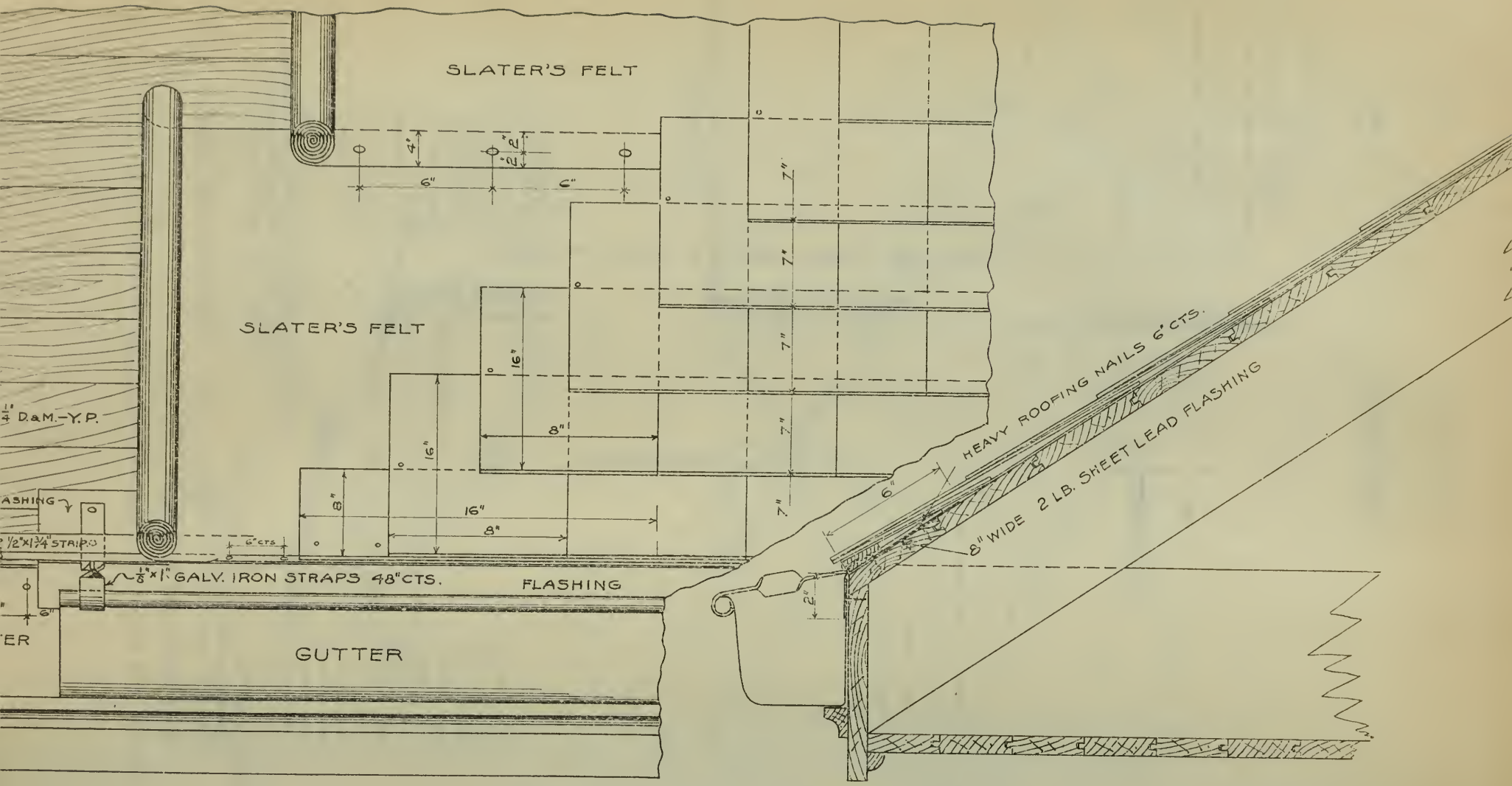
VERTICAL CONTINUOUS FOOT FLASHING
FOOT FLASHING AGAINST
PERPENDICULAR WALLS

№ 2-6-8-9-11-14

DETAILS OF FLASHING AND COUNTER FLASHING FOR ROOFS AND WALLS.

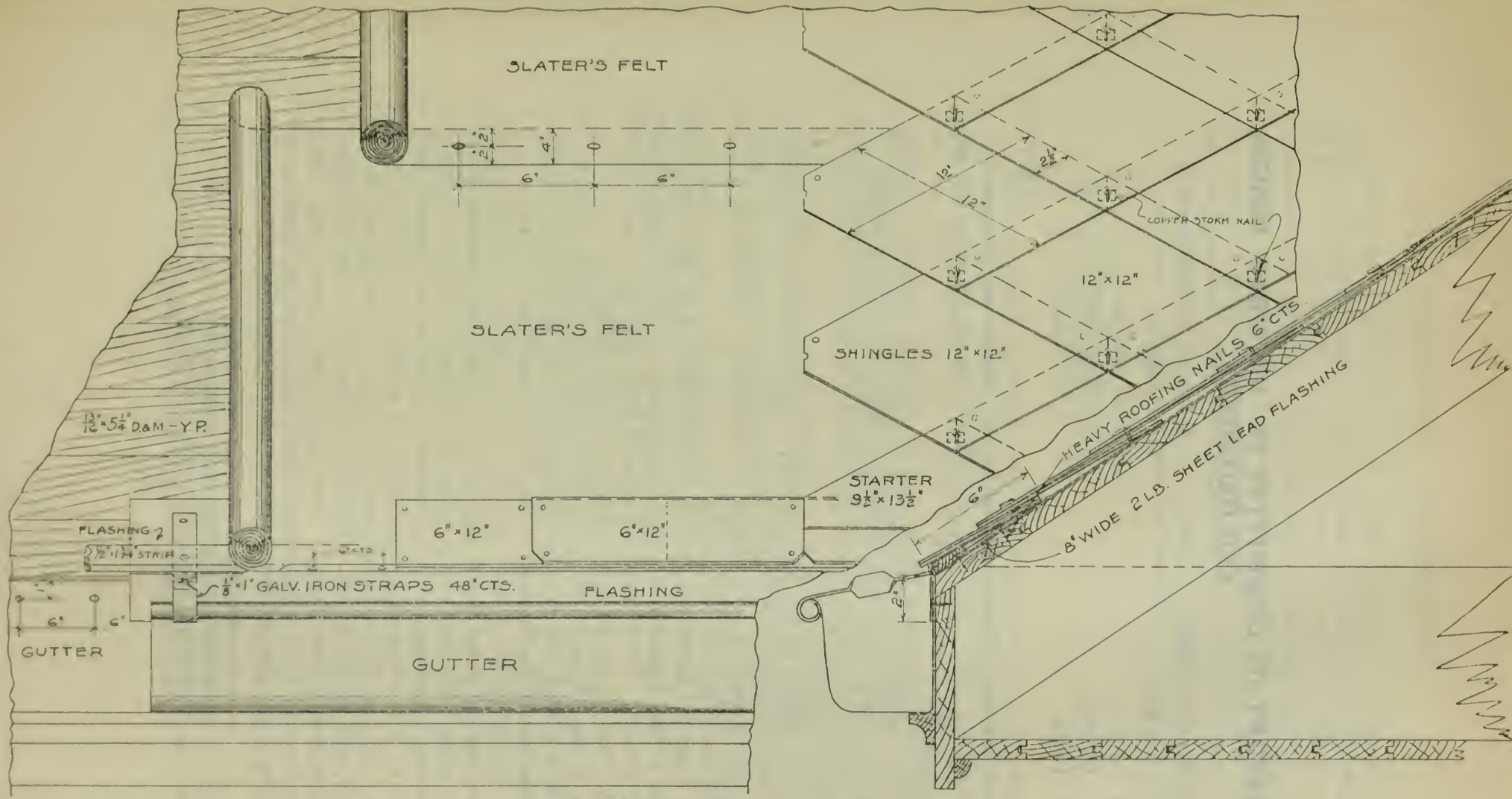
FULL SIZE COPPER STORMNAIL
SHOWING STORMNAIL BENT OVER TOP SHINGLE
COPPER STORMNAIL
SHOWING STORM NAIL UNDER SHINGLES

AMERICAN METHOD OF LAYING ASBESTOS SHINGLES.



American Method of Laying Asbestos Shingles.

Apply one course of 8-in. by 16-in. shingles, at eaves, lengthwise and parallel to same, overhanging the eaves about ½ in. Apply the second course, using same style shingle, entirely covering course, breaking joints, after which proceed in the regular manner as with wooden shingles or slate, exposing 7 in. to the weather, and fastening each shingle in place with at least two roofing nails.



DIAGONAL METHOD OF LAYING ASBESTOS SHINGLES.

Apply one course of 6-in. by 12-in. asbestos shingles end to end, parallel with and overhanging the eaves about ½ in., over which apply one course of 6-in by 12-in. shingles, entirely covering the first kind, breaking all joints. Starter 9½ in. by 13½ in. shall then be applied, exposing one-half lower course of the 6-in. by 12-in., as shown in detail above. Cover the balance of the roof with 12-in. by 12-in. shingles, laid as shown, exposing 9½ in. by 9½ in. to the weather. Securely fasten all shingles to place with at least two roofing nails, and fasten the points of the main body shingles with special storm nails. All the main body shingles shall be laid with the diagonal lines on a 45-degree angle with the eaves. Other sizes of shingles can be obtained in the same pattern.

REPORT OF COMMITTEE IX—ON SIGNS, FENCES AND CROSSINGS.

C. H. Stein, *Chairman;*
H. E. Billman.
G. E. Boyd.
L. C. Lawton.
E. R. Lewis.
A. M. Funk, *Vice-Chairman;*
J. B. Myers.
F. M. Patterson.
C. H. Splitstone.
W. D. Williams.

Committee.

To the Members of the American Railway Engineering Association:

The following subjects were assigned your Committee by the Board of Direction:

(1) Continue the investigation of ways and means for securing a proper quality of fence wire to resist corrosion and secure durability.

(2) Report on the relative advantages and disadvantages of the different kinds of fence posts.

(3) Report on the best form of track construction and flangeways at street crossings in paved streets.

(4) Report on the relative advantages and disadvantages of the different kinds of telegraph poles.

A general Committee meeting was held at the Fort Pitt Hotel, Pittsburg, Friday, September 22, 1911, at 10:00 a. m., which discussed the subjects assigned. Those present were C. H. Stein, Chairman; H. E. Billman, G. E. Boyd, E. R. Lewis, L. C. Lawton, W. D. Williams.

In the afternoon the Committee visited the Donora plant of the American Steel and Wire Company, and investigated their process of making wire from the ingot to the finished woven wire product.

The Committee decided to devote its attention to the first three subjects assigned by the Board of Direction, and also to investigate the general subject of miscellaneous signs for railroad purposes. A series of questions were prepared for submission to the various railways with a view to determining the practice in vogue at this time and to secure the benefit of data that had been accumulated from experiments made in recent years with various forms of fencing wires, and by various processes, as well as with various kinds of wooden and concrete fence posts. Replies were received from 44 railways of the United States and Canada, representing 61,000 miles of track, which developed the following information:

(1) 28 roads are using woven wire exclusively;
6 roads are using barb wire exclusively;
2 roads are using ribbon wire exclusively;
5 roads are using both barb and woven wire.

Woven wire 49 in. to 55 in. in height appears to be generally used. Specifications in use refer merely to method, form of erection, and style of fence, and give practically no consideration to quality of wire or process of manufacture. The wire companies seem to control this latter feature exclusively. In a couple of cases compliance with the specifications of the American Railway Engineering Association is recommended but not explicitly demanded. Only two of the roads are making any experiments in the development of the subject. Experiments in one case, started April 1, 1909, are being conducted with wires grouped in four classes, as follows:

(a) Galvanized after weaving;
(b) Ordinary dip process;
(c) Special galvanized;
(d) Sherardized.

When examination was last made, less than a year ago, (a), galvanized after weaving, was found to be in perfect condition: (b), ordinary dip process, began to corrode during the first year. The corrosion was not so rapid during the second year, but was sufficiently progressive to indicate that deterioration would soon become serious, and the wire go to pieces at points where stay wires were woven around the longitudinal ones; (c), special galvanized, was found to be in excellent condition. No corrosion was apparent, and the wires were still bright. This process is still in an experimental stage, and investigations will be continued. (d), Sherardized. This is a process in which the wire is placed in air-tight receptacles and zinc flue dust packed about it. The receptacles are then heated for a given period of time at a temperature somewhat below the melting point of zinc, the zinc forming a coating over the wires. At the time the test was commenced, this process was not yet far advanced, and later developments may give some promise of success. The results in this case, however, were not good.

Similar tests were commenced under the auspices of the American Society for Testing Materials on the grounds of the Carnegie Technical School, Pittsburg, Pa., on September 26, 1908. The results of these tests will be watched with interest and profit. Several rolling mills are now rolling what is claimed to be a pure metal, running about 99.95 per cent. pure iron, and exceedingly low in sulphur, carbon and phosphorus. This is being used for a variety of purposes, and we understand that it can be drawn into wire. This may develop into a proper material for wire making purposes with efficient rust resisting properties.

Copper clad wire is also a form of material that is attracting considerable attention. This consists of a steel core surrounded by a copper jacket applied by mechanical means. The American Consul at Birmingham recently called the attention of the State Department of this Government to the announcement in a British Journal of a new rust-proofing process for iron and steel that is said to be cheap and efficient.

The article to be protected is boiled in a solution whose proportions are: Water, one gallon; phosphoric acid, four ounces, and one ounce of

iron filings. This produces a black non-corroding coating that is durable. These different products and methods will be further investigated during the coming year.

It might be stated that English roads use a much heavier wire than those in this country, usually No. 4 to No. 6 gage. All of it is unwiped, and it is said they use a better grade of spelter than we do.

At the present time, undoubtedly the wire galvanized after weaving has proved most durable and efficient, but only certain forms of weaving appear at this writing to be adapted to that process. Progress is being made, however, and if tests now being conducted demonstrate that this is the only manner in which desired results may be obtained, the larger wire mills will discover a means of accomplishing it if the railway companies insist upon it.

(2) Report on the relative advantages and disadvantages of the different kinds of fence posts.

Nine roads which replied to circular are beginning to use concrete posts, and we know of others using them, which gave us no information. Experiments have been conducted for too short a period, however, to enable them to make a definite statement as to their durability, economy and efficiency.

The tendency toward the use of concrete posts, however, is becoming very pronounced, and we should in the course of the next year or so be able to secure some very valuable and satisfactory information. The prices for concrete posts appear to vary between 18 and 40 cents, but the figure largely prevailing for the most popular form of post now on the market is 18 to 22 cents. Since the cost of the various kinds of wood posts now in use ranges from 12 cents to 40 cents, the prevailing cost being 12 to 15 cents, the difference is not so great as to act as a prohibition to the use of concrete. The woods used are necessarily those native to the road and consist of Oregon fir; red, white and Michigan cedar; black, yellow and honey locust; catalpa; tamarack; mulberry, juniper; bois d'arc, chestnut; white and pin oak.

Several forms of metal posts are now being manufactured, and it is claimed by a large manufacturer that they will have a life of at least thirty years and can be delivered at reasonable distances at a price of 23 cents f. o. b. line of road. These will also receive our attention during the current year, in connection with the further investigation of concrete posts.

(3) Report on the best form of track construction and flangeways at street crossings in paved streets.

The customary practice is the very old one of turning an old light rail on its side and backing it up with wood plank, planking solid with wood or planking next to rail and paving with blocks or brick between. The rail or plank forms the flangeway. Five roads of the forty-four referred to use some special form of rail or flangeway through paved

streets. In several of the cases a 141-lb. girder rail is employed with suitable compromise bars at each end to connect to the tee-rail sections. In three cases a special form of rolled filler or flangeway, similar to angle bar construction, with extension beyond the rail head similar to street car flangeways, is being considered and gives promise of successful application. Correspondence is now in progress with the steel company to roll a trial order, and it is hoped the experiment may be made during the course of this year, which would perhaps enable us to make a definite recommendation at the next convention.

(4) Report on the relative advantages and disadvantages of the different kinds of telegraph poles.

This subject was not investigated, as very few experiments have thus far been conducted with this form of construction. The industry is growing, however, and attention will be given it this year.

SIGNS FOR RAILROAD PURPOSES.

There is a growing demand for uniformity of signs for all railroad purposes. It is obvious that it would be a desirable end to be obtained if all signs for use in giving information to the public or employés were of a similar design in all parts of the country. The Committee has been investigating the subject with the purpose of producing uniformity, and securing substantial and economic signs, but has not progressed to the point where a conclusion can be reached. It will recommend the subject for definite recommendations at the next convention.

Much information has been received in regard to the foregoing subjects, but it has not been in a sufficiently substantial form, nor in the nature of such new information, that would warrant the Committee in making any recommendations in the shape of conclusions. The various subjects, however, are in a progressive stage, and with the mass of information now at hand it appears that the Committee will be enabled at the next convention to put the matters in definite shape.

We have been handicapped very much in failing to secure information from our letters of inquiry. Many roads from whom we expected to get beneficial data have failed entirely to reply to our circulars for information. It is possible that this is due to the fact that there are so many committees of the Association reporting on so many different subjects that it is practically impossible for the engineering officers to compile the necessary information and satisfy all of the inquiries. The solution to this problem would, therefore, be that fewer subjects should be assigned for investigation and thus relieve the roads of the great amount of labor that is now necessary in securing and compiling the data on the multitude of subjects on which information has been sought during past years.

The matter of a proper quality of fencing wire to resist corrosion and secure durability has been under consideration by the American Society

for Testing Materials, and we would, therefore, make the following recommendations:

(1) That the Board of Direction instruct our Committee to endeavor to co-operate with a similar committee of the American Society for Testing Materials in reaching a conclusion on this latter subject.

(2) That subjects Nos. 2, 3 and 4, assigned last year, be reassigned for study and a report made when the Committee considers that it has sufficient data to warrant conclusions.

(3) That the Board of Direction assign the subject of "Uniform Railway Signs for all purposes as applicable to the Public and to Railway Operation."

Respectfully submitted,

COMMITTEE ON SIGNS, FENCES AND CROSSINGS.

REPORT OF COMMITTEE XVI—ON ECONOMICS OF RAILWAY LOCATION.

A. K. Shurtleff, *Chairman;*
C. Frank Allen.
Willard Beahan.
C. K. Conard.
A. C. Dennis.
C. P. Howard.
W. A. James.
R. N. Begien, *Vice-Chairman;*
Fred Lavis.
C. J. Parker.
F. W. Smith.
Francis Lee Stuart.
Walter Loring Webb.
M. A. Zook.

Committee.

To the Members of the American Railway Engineering Association:

Your Committee realizes that some of the members of our Association may be disappointed in its failure to produce a report having some logical conclusions. The failure to report at the 1911 convention was explained at the time, but during the past year the Committee has been greatly encouraged in its work by the receipt of considerable valuable operating information.

Under date of October 26, 1911, the Chairman was able to send to such members of the Committee as had shown any interest in the work a tabulated statement by accounts of the operating costs of nine large railways, comprising 13 per cent. of the main track mileage of the United States, over 18 per cent. of the freight train mileage, and over 16 per cent. of the passenger train mileage. In some cases the more important accounts covering "Conducting Transportation" were separated between Passenger and Freight Service, which will be of particular value to your Committee in the final analysis of the questions to be considered.

In addition to the cost data, information has been tabulated covering the density of traffic per mile of main track in train miles, car miles and ton miles.

The working members of your Committee have been devoting such time as they could spare to the study of the statistics tabulated, and to a portion of them it becomes apparent that no fixed values can be established for distance, curvature, rise and fall, or gradient. A careful study of the data covering costs by primary accounts apparently indicates that costs in some of the accounts vary with the number of train miles and the ratio of freight train mileage to passenger train mileage.

In other cases the logical unit of variation is the ton mile, or car mile depending entirely on the account in question. Further, the density of traffic both as to train mileage and ton mileage enters into the costs.

The result is that your Committee has refrained from presenting any conclusions for your consideration until it has had time to thoroughly digest the information now at hand.

A portion of your Committee believes that each case must be considered by itself, with a probability that the values used for the unit costs will vary widely, depending on local conditions of traffic with reference to car loading, character and density of traffic, etc., and in some cases on climatic conditions.

Your Committee hopes to present a report during the coming year which will show one or more methods of practical analysis of the question covering conditions that exist with each case.

Respectfully submitted,

A. K. SHURTLEFF, *Chairman.*

REPORT OF SPECIAL COMMITTEE ON UNIFORM GENERAL CONTRACT FORMS.

J. C. IRWIN, *Chairman.*
E. F. ACKERMAN.
W. L. BRECKINRIDGE.
R. G. KENLY.
E. H. LEE.
C. A. PAQUETTE.
W. G. ATWOOD, *Vice-Chairman.*
H. C. PHILLIPS.
J. H. ROACH.
H. A. WOODS.
C. A. WILSON.
Committee.

To the Members of the American Railway Engineering Association:

Your Special Committee on Uniform General Contract Forms presents progress report as follows:

The Committee was instructed by the Board of Direction to report on "General Contract Forms."

General meetings of the Committee were held as follows: At Burlington, Vt., August 30, 1911, attended by J. C. Irwin, Chairman; W. G. Atwood, C. A. Paquette, J. H. Roach, H. A. Woods; at Buffalo, N. Y., September 29, 1911, attended by J. C. Irwin, Chairman; E. H. Lee, C. A. Paquette, H. A. Woods, C. A. Wilson.

The text of the report of the Committee, published in Bulletin 133, of March, 1911, was thoroughly discussed and revised, and the reports of the Committee on Buildings, published in Bulletin 68, and of the Special Contract Committee, made at the Tenth Annual Convention in 1909 and published in Bulletin 108, have been studied. As the report of March, 1911, in Bulletin 133, was not acted upon, the following portion of that report may be repeated:

"The plan of having an agreement form of two pages separate from the general contract conditions and as referred to on page 1176 of the Proceedings of the Tenth Annual Convention, is approved by this Committee, and the agreement form presented in that report has been reconsidered and revised and is presented herewith with recommendations for adoption.

"In small or unimportant contracts this agreement form, which is designated as Form A, may be used alone, but in larger contracts the General Conditions statement designated as Form B may be inserted, using the agreement form as a folder with the introductory page at the beginning of the contract and the signature at the end.

"Specifications relating to the particular work can either be included in the folder or attached to the back.

"The Committee has, in the agreement, made the 'Contractor' the party of the first part, and the 'Company' the party of the second part, and has, therefore, in preparing the 'General Conditions,' placed the provisions relating especially to the duties and rights of the 'Contractor' first and those relating to the duties and rights of the 'Company' last."

The Committee has considered and presents herewith, for discussion, the form suggested for Agreement A, and also the following sections for the General Conditions B:

1. Bond.
2. Contractor's Understanding.
3. Intent of Plans and Specifications.
4. Permits.
5. Protection.
6. Rights of Various Interests.
7. Consent to Transfer.
8. Superintendence.
9. Timely Demand for Points and Instructions.
10. Report Errors and Discrepancies.
11. Preservation of Stakes.
12. Inspection.
13. Defective Work or Material.
14. Insurance.
15. Indemnity.
16. Settlement for Wages.
17. Liens.
18. Work Adjacent to Railroad.
19. Risk.
20. Order and Discipline.
21. Contractor Not to Hire Company's Employes.
22. Intoxicating Liquors Prohibited.
23. Cleaning Up.
24. Engineer and Chief Engineer Defined.
25. Power of Engineer.
26. Adjustment of Dispute.
27. Order of Completion. Use of Completed Portions.
28. Changes.
29. Extra Work.
30. Property and Right of Entry.
31. Unavoidable Delays. Extension of Time on Parts of Work.
32. Suspension of Work.
37. Monthly Estimate.

The Committee has discussed, but not formally acted upon, the following Sections, 33, 34, 35, 36 and 38.

The Committee especially presents for approval:

(1) The general scheme of having the two-page general agreement, Form A, as a folder, within which the other portions of the contract can be bound, thus permitting a concise contract form or a large contract form, according to the requirements of the case.

(2) The Agreement—Form A—as presented herewith.

(3) Sections 1 to 32 and Section 37 of B General Conditions.

For next year's work recommendations are made as follows:

(1) Reconsider standard contract form so far as presented in the light of discussions presented at the convention or by letter.

(2) Complete the construction of final sections of contract.

(3) Consider advisability of having any supplementary standard forms in conjunction with Uniform General Contract Form, and prepare such contract forms as may be considered advisable.

Respectfully submitted,

SPECIAL COMMITTEE ON UNIFORM GENERAL CONTRACT FORMS.

CONSTRUCTION CONTRACT

A—AGREEMENT.

THIS AGREEMENT, made this ..... day of ..... in the year ..... by and between ..... party of the first part, hereinafter called the Contractor, and .... party of the second part, hereinafter called the Company.

WITNESSETH, That, in consideration of the covenants and agreements hereinafter mentioned, to be performed by the parties hereto and of the payments hereinafter agreed to be made, it is mutually agreed as follows:

The Contractor shall furnish all the necessary transportation, materials, superintendence, labor and equipment, and shall execute, construct and finish, in an expeditious, substantial and workmanlike manner, to the satisfaction and acceptance of the Chief Engineer of the Company.

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in accordance with the plans hereto attached or as herein described, and the following general conditions, requirements and specifications, forming part of this contract.

The work covered by this contract shall be commenced .... and be completed on or before the ..... day of ....., 191.., ...
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And in consideration of the completion of the work described herein, and the fulfillment of all stipulations of this agreement to the satisfaction and acceptance of the Chief Engineer of the Company, the said Company shall pay, or cause to be paid, to said Contractor, the amount due the Contractor, based on the following prices:

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This agreement shall inure to the benefit of and be binding upon the legal representatives and successors of the parties respectively.

In Witness Whereof, The parties hereto have executed this agreement in ..... the day and year first above written.

Witness:

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CONSTRUCTION CONTRACT.

B. GENERAL CONDITIONS.

Bond.

1. The Contractor agrees, at the time of the execution and delivery of this contract and before the taking effect of the same, to furnish and deliver to the Company a good and sufficient bond of indemnity to the amount of ..... dollars, as security for the faithful performance, by the Contractor, of all the covenants and agreements on the part of the Contractor contained in this contract. The security in such bond of indemnity must be satisfactory and acceptable to the Company.

This bond shall remain in force and effect in such amount, not greater than that specified, as shall be determined by the Chief Engineer, until the final completion and acceptance of the work.

Contractor's Understanding.

2. It is understood and agreed that the Contractor has, by careful examination, satisfied himself as to the nature and location of the work, the conformation of the ground, the character, quality and quantity of the materials to be encountered, the character of equipment and facilities needed preliminary to and during the prosecution of the work, the general and local conditions, and all other matters which can in any way affect the work under this contract. No verbal agreement or conversation with any officer, agent or employe of the Company, either before or after the execution of this contract, shall affect or modify any of the terms or obligations herein contained.

Intent of Plans and Specifications.

3. All work that may be called for in the specifications and not shown on the plans, or shown on the plans and not called for in the specifications, shall be executed and furnished by the Contractor as if described in both these ways; and should any work or material be required which is not denoted in the specifications or plans, either directly or indirectly, but which is nevertheless necessary for the proper carrying out of the obvious intentions thereof, the Contractor is to understand the same to be implied and required, and shall perform all such work and furnish any such material as fully as if they were particularly delineated or described.

Permits.

4. Permits of a temporary nature necessary for the prosecution of the work shall be secured by the Contractor. Permits for permanent structures or permanent changes in existing facilities shall be secured by the Company.

Protection.

5. Whenever the local conditions, laws or ordinances require, the Contractor shall furnish and maintain, at his own cost and expense, necessary passageways, guard fences and lights and such other facilities and means of protection as may be required.

Rights of Various Interests.

6. Wherever work being done by Company forces or by other Contractors is contiguous to work covered by this contract the respective rights of the various interests involved shall be determined by the Engineer, to secure the completion of the various portions of the work in general harmony.

Consent to Transfer.

7. The Contractor shall not let or transfer this contract or any part thereof (except for the delivery of material) without consent of the Chief Engineer, given in writing. Such consent does not release or relieve the Contractor from any or all of his obligations and liabilities under the contract.

Superintendence.

8. The Contractor shall constantly superintend all the work embraced in this contract, in person or by a duly authorized manager acceptable to the Company.

Timely Demand for Points and Instructions.

9. The Contractor shall not proceed until he has made timely demand upon the Engineer for, and has received from him, such points and instructions as may be necessary as the work progresses. The work shall be done in strict conformity with such points and instructions.

Report Errors and Discrepancies.

10. If the Contractor, in the course of the work, finds any discrepancy between the plans and the physical conditions of the locality, or any errors in plans or in the layout as given by said points and instructions, it shall be his duty to immediately inform the Engineer. Any work done after such discovery, until verified, will be done at the Contractor's risk.

Preservation of Stakes.

11. The Contractor must carefully preserve bench marks, reference points and stakes, and in case of wilful or careless destruction, he will be charged with the resulting expense and shall be responsible for any mistakes that may be caused by their unnecessary loss or disturbance.

Inspection.

12. All work and materials shall be at all times open to the inspection, acceptance or rejection of the Engineer or his duly authorized representative. The Contractor shall at all times provide reasonable and necessary facilities for such inspection.

Defective Work or Material.

13. Any omission or failure on the part of the Engineer to disapprove or reject any work or material shall not be construed to be an acceptance of any defective work or material. The Contractor shall remove, at his own expense, any work or material condemned by the Engineer, and shall rebuild and replace the same without extra charge, and in default thereof the same shall be done by the Company at the Contractor's expense—or, in case the Chief Engineer should not consider the defect of sufficient importance to require the Contractor to rebuild or replace any imperfect work or material, he shall have power, and is hereby authorized, to make any deduction from the stipulated price that he may deem proper.

Insurance.

14. The Contractor shall secure in the name of the Company and for its benefit, policies of fire insurance on such structures and in such amounts as shall be specified by the Chief Engineer not exceeding .....

Indemnity.

15. The Contractor shall indemnify and save harmless the Company for and from all claims, demands, payments, suits, actions, recoveries and judgments of every nature and description brought or recovered against it, by reason of any act or omission of the said Contractor, his agents or employes, in the execution of the work by or in consequence of any negligence or carelessness in guarding the same.

Settlement for Wages.

16. Whenever, in the opinion of the Chief Engineer, it may be necessary for the progress of the work to secure to any of the employes of the Contractor any wages which may then be due them, the Company is hereby authorized to pay said employes the amount due them or any lesser amount, and the amount so paid them, as shown by their receipts, shall be deducted from any moneys that may be or become payable to said Contractor.

Liens.

17. If an established lien be filed against the Contractor for labor or material furnished in the performance of the work, the Company is hereby authorized to pay and discharge the same, if it shall deem best so to do, and to deduct the amount so paid from any moneys which may be or become due and payable to the Contractor.

Work Adjacent to Railroad.

18. Whenever the work embraced in this contract is near the tracks, structures or buildings of this Company or of other railroads, the Contractor shall use proper care and vigilance to avoid injury to persons or property. The work must be so conducted as not to interfere with the movement of trains or other operations of the railroad; or, if in any case such interference be necessary, the Contractor shall not proceed until he has first obtained specific authority and directions therefor from the proper officer of the Company and has the approval of the Engineer.

Risk.

19. The work in every respect shall be at the risk of the Contractor until finished and accepted, except damage or injury caused directly by Company's agents or employes.

Order and Discipline.

20. The Contractor shall at all times enforce strict discipline and good order among his employes, and any employe of the Contractor who shall appear to be incompetent, disorderly or intemperate, or in any other way disqualified for or unfaithful to the work entrusted to him, shall be discharged immediately on the request of the Engineer, and he shall not again be employed on the work without the Engineer's written consent.

Contractor Not to Hire Company's Employes.

21. The Contractor shall not employ or hire any of the Company's employes without the permission of the Engineer.

Intoxicating Liquors Prohibited.

22. The Contractor, in so far as his authority extends, shall not permit the sale, distribution or use of any intoxicating liquors upon or adjacent to the work, or allow any such to be brought upon, to or near the line of the railway of the Company.

Cleaning Up.

23. The Contractor shall, as directed by the Engineer, remove from the Company's property and from all public and private property, at his own expense, all temporary structures, rubbish and waste materials resulting from his operations.

Engineer and Chief Engineer Defined.

24. Wherever in this contract the word Engineer is used, it shall be understood as referring to the Chief Engineer of the Company, acting personally or through an assistant duly authorized in writing for such

act by the Chief Engineer, and wherever the words Chief Engineer are used it shall be understood as referring to the Chief Engineer in person, and not to any assistant engineer.

Power of Engineer.

25. The Engineer shall have full power to reject or condemn all work or material, which, in his opinion, does not conform to this contract; to direct the application of forces to any portion of the work which, in his judgment, requires it; to order the force increased or diminished, and to decide every question that may arise between the parties relative to the execution of the work.

Adjustment of Dispute.

26. All questions or controversies which may arise between the Contractor and the Company, under or in reference to this contract, shall be subject to the decision of the Chief Engineer, and his decision shall be final and conclusive to both parties.

Order of Completion; Use of Completed Portions.

27. The Contractor shall complete any portion or portions of the work in such order of time as the Engineer may require. The Company shall have the right to take possession of and use any completed or partially completed portions of the work, notwithstanding the time for completing the entire work or such portions may not have expired; but such taking possession and use shall not be deemed an acceptance of the work so taken or used or any part thereof. If such prior use increases the cost of or delays the work, the Contractor will be entitled to such extra compensation, or extension of time, as the Chief Engineer may determine.

Changes.

28. The Company shall have the right to make any changes that may be hereafter determined upon, in the nature or dimensions of the work, either before or after its commencement, and such changes shall in no way affect or void this contract. If such changes diminish the quantity or extent of the work to be done, they shall not, under any circumstances, be construed as constituting, and shall not constitute a claim for damages or for anticipated profits on such work.

In case quantities in the completed work vary from the quantities shown on the original plans, and provided for in the specifications, then the final payment shall be adjusted on the basis of unit rates specified in this contract.

Note.—First paragraph of Section 28 to be used in unit price and force account contracts, i. e., in all contracts not on lump-sum prices. Should be omitted in lump-sum contracts.

Extra Work.

29. No bill or claim for extra work or material shall be allowed or paid unless the doing of such extra work or the furnishing of such extra material shall have been authorized in writing by the Engineer before any part of such work was done or material furnished.

The price for such work shall be determined by the Chief Engineer, who may either fix a unit price or a lump-sum price, or may, if he so elects, provide that the price shall be determined by the actual cost, to which shall be added ..... per cent. to cover general expense and superintendence, profits, contingencies, use of tools, Contractor's risk and liability. If the Contractor shall perform any work or furnish any material which is not provided for in this contract, or which was not authorized in writing by the Engineer previous to the doing of the work or the furnishing of material, said Contractor shall receive no compensation for such work or material so furnished, and does hereby release and discharge the Company from any payment therefor.

If the Contractor shall proceed with such extra work or the furnishing of such extra material after receiving the written authority therefor, as hereinbefore provided, then such work or material, stated in the written authority of the Engineer, shall be covered, governed and controlled by all the terms and provisions of this contract, subject to such prices as may be agreed upon or fixed by the Chief Engineer.

If the Contractor shall decline or fail to perform such work or furnish such extra material as authorized by the Engineer in writing, as aforesaid, the Company may then arrange for the performance of the work in any manner it may see fit, the same as if this contract had not been executed, and the Contractor shall not interfere with such performance of the work.

Property and Right of Entry.

30. The Company shall provide the lands upon which the work under this contract is to be done, except that the Contractor shall provide land required for the erection of temporary construction facilities and storage of his material, together with right of access to the same.

The Contractor shall not enter upon said lands, nor ship any material or equipment, until he has received written notice from the Engineer that he may proceed with said work or any part thereof.

Unavoidable Delays; Extension of Time on Parts of Work.

31. If the Contractor shall be delayed in the performance of the work from any cause, for which the Company is responsible, he shall, upon written application to the Chief Engineer at the time of such delay, be granted such extension of time as the Chief Engineer shall deem equitable and just.

Suspension of Work.

32. The Company may at any time stop the work, or any part thereof, by giving ten (10) days' notice to the Contractor in writing. The work shall be resumed by the Contractor in ten (10) days after the date fixed in the written notice from the Company to the Contractor so to do. The Company shall not be held liable for any damages or anticipated profits on account of the work being stopped, or for any work done during the interval of suspension. It will, however, pay the Contractor for expense of men and teams necessarily retained during the interval of suspension, provided the Contractor can show that it was not reasonably practicable to move these men and teams to other points at which they can be engaged. The Company will further pay the Contractor for time necessarily lost during such suspension at the rate of ..... per cent. per annum on the estimated value of all equipment and fixtures owned by the Contractor and employed on the work which are necessarily idle during such suspension, said rate of ..... per cent. per annum being understood to include depreciation, interest and insurance. But if the work, or any part thereof, shall be stopped by the notice in writing aforesaid, and if the Company does not give notice in writing to the Contractor to resume work at a date within ..... of the date fixed in the written notice to suspend, then the Contractor may abandon that portion of the work to suspend and he will be entitled to the estimates and payments for such work so abandoned, as provided in Sections ..... of this contract.

Annulment, Contractor's Fault.

33. Discussed, but not acted upon by the Committee.

Annulment, Without Fault of Contractor.

34. Discussed, but not acted upon by the Committee.

Removal of Equipment in Case of Annulment.

35. Discussed, but not acted upon by the Committee.

Measurement and Approval of Work.

36. Discussed, but not acted upon by the Committee.

Monthly Estimate.

37. So long as the work herein contracted for is prosecuted in accordance with the provisions of this contract, and with such progress as may be satisfactory to the Chief Engineer, the said Chief Engineer will, on or about the first day of each month, make an approximate estimate of the proportionate value of the work done and of material furnished or delivered upon the Company's property at the site of the work, up to and including the last day of the previous month. The amount of said estimate, after deducting ..... per cent. and all previous payments, shall be due and payable to the Contractor at the office of the Treasurer of the Company on or about the 20th day of the current month.

Final Estimate.

38. Discussed, but not acted upon by the Committee.

DISCUSSIONS

DISCUSSION ON RULES AND ORGANIZATION.

(For Report, see pp. 65-68.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON RULES AND ORGANIZATION.

F. D. ANTHONY.
A. S. BALDWIN.
J. B. BERRY.
W. M. CAMP.
H. M. CHURCH.
L. A. DOWNS.
C. H. EWING.
ROBERT FERRIDAY.
H. E. HALE.
E. R. LEWIS.
G. W. MERRELL.
C. A. MORSE.
H. T. PORTER.
E. T. REISLER.
L. S. ROSE.
C. H. STEIN.
JOHN G. SULLIVAN.
E. E. R. TRATMAN.
WALTER LORING WEBB.
EDWIN F. WENDT.
C. C. WENTWORTH.
H. S. WILGUS.

The President:—We will now take up the report of the Committee on Rules and Organization. Mr. Osgood, the Chairman of the Committee, at the last minute, was prevented from coming here, so that he has not had an opportunity to instruct the other members of his Committee fully as to the preliminary announcements. Mr. F. D. Anthony will be kind enough to state the general work of the Committee in order that the report may be discussed.

Mr. F. D. Anthony (Quebec, Montreal & Southern):—The report of the Committee is well set forth in Bulletin 141, and I do not know that there is much to say on the subject except to leave it to the convention for criticism.

The President:—The first recommendation of the Committee is on the first page, in which they state, "That no change be made in the General Rules for the Government of Employés of the Maintenance of Way Department heretofore adopted by the Association." Then they state "That to the rules heretofore adopted by the Association be added Instructions as follows:" Then follows a list of 26 rules. What is your pleasure in regard to the consideration of these instructions or rules? If agreeable we will adopt the usual course, and have the Secretary read each paragraph, and any members having any criticisms to make will please state them; the adoption of each separate paragraph will not be put to vote, except in the case of a dispute, or something of that nature.

(The Secretary then read the paragraphs under the heading Instructions.)

The Secretary:—"(1) The roadbed, ballast and track shall conform to the standard plans. No changes in the sections shown shall be made without proper authority.

"(Note: It is understood that cross-sections for wet cuts will be included in the standard plans.)

"(2) All ditches, including intercepting ditches on the upper side of cuts, must be kept clean.

"(3) Where heaving or wet spots develop, special drainage shall be provided."

The President:—Mr. Tratman has a suggestion to make in regard to No. 3.

Mr. E. E. R. Tratman (Engineering News):—My suggestion is that after the word "develop" we insert the words "investigation as to cause must be made," so that it will read, "Where heaving or wet spots develop, investigation as to cause must be made and special drainage provided."

Mr. F. D. Anthony:—We might add "Investigation" to every rule of similar nature. Investigation is a foregone conclusion. The Committee think that is unnecessary.

The President:—Do you wish to make any motion as to that, Mr. Tratman?

Mr. Tratman:—No.

The Secretary:—"(4) Before re-ballasting track, line and grade stakes shall be set by the Engineer. All unsuitable material shall be removed and the roadbed widened to proper section, the waste material being used to widen banks, or otherwise, as may be directed.

"(5) Track must be kept in good line and surface while ballasting, open track avoided as far as practicable, and such track carefully watched."

Mr. Tratman:—It seems to me that sentence is rather long, especially as it deals with two distinct subjects. I propose that it be divided into two parts, to read, "Track must be kept in good line and surface while ballasting. Open track must be avoided as far as practicable, and such track carefully watched."

Mr. F. D. Anthony:—That is merely a matter of punctuation.

The President:—Is the Committee willing to accept it?

Mr. F. D. Anthony:—No; we would prefer to let the rule stand as recommended in the report.

The President:—Do you wish to make a motion? Any further criticism?

The Secretary:—"(6) After ballast is distributed it shall be trimmed, and the track lined and surfaced to conform to the standard plans."

Mr. Tratman:—I seem to be coming unduly to the front here, but it seems as if that paragraph could be changed grammatically and be improved by wording it as follows: "After ballast is distributed, it shall be trimmed to conform to the standard plans, and the track lined and surfaced." We do not line and surface to the standard plans (as worded in the original), but the track is to be trimmed to the standard plans.

Mr. F. D. Anthony:—It is my opinion and also the opinion of one other member of the Committee that rule No. 6 is not right, as ballast is usually distributed in anticipation of a lift. It seems to me the lift is the first thing after the distribution of the ballast, and I would suggest

this: "After ballast is distributed and the track lifted, the track should be lined and surfaced and the ballast trimmed to conform to standard plans."

(Motion seconded and carried.)

The Secretary:—"(7) Where track is bonded, ballast must be kept at least one inch below the base of rail. At road crossings, platforms, etc., where this is not practicable, only clean gravel or rock ballast shall be used."

Mr. Tratman:—I move that the word "electrically" be inserted before "bonded." We all know what "bonded" means, but as these are rules to be sent out for trackmen and track officials, I think it should be explained more fully.

The President:—The Acting Chairman says there is no objection to making that change.

The Secretary:—"(8) Ties stored along right-of-way shall be piled to conform to the standard plan.

"(Note: The standard plan should show the minimum distance to the nearest rail.)

"(9) The ties in track must be inspected at stated times each year and those which will not last until the next inspection marked for renewal.

"(10) The renewal of ties shall be started when directed by the .....(Title)..... When ties are being renewed, the line and surface shall be corrected and ballast trimmed."

Mr. H. M. Church (Baltimore & Ohio):—I would like to change the last three words of Rule 10 "and ballast trimmed," so that it shall read, "unsuitable material removed and ballast trimmed."

Mr. F. D. Anthony:—There is no objection to that.

The Secretary:—"(11) All defective ties removed from track shall each day be placed for burning or loading on cars."

Mr. Tratman:—I propose a little grammatical change there. Instead of "shall each day," substitute "removed from track each day shall be placed for burning or for loading on cars."

Mr. F. D. Anthony:—The Committee does not see any object in changing the wording as recommended.

The Secretary:—"(12) The.....(Title)..... shall frequently inspect ties removed from track to see if any have been removed which might have remained in the track with safety until the next inspection."

Mr. Tratman:—I think that could be simplified in the second line; instead of "if any have been removed which might have remained," substitute "if any of them have been removed." That makes it a little less involved.

Mr. F. D. Anthony:—There is no objection to that correction.

The President:—The Committee accepts that.

The Secretary:—"(13) Ties shall be spaced according to the standard plans. All ties shall be placed square to the line of rails. The outside ends on double tracks, and the ends on one side throughout on single track, must be lined parallel with the rail.

"(14) The heart side of ties must be turned down. The largest and best ties shall be selected for use at joints. Twisted or badly hewn ties must not be notched, but the bearings must be made true with the adze."

Prof. Walter Loring Webb (Consulting Engineer):—I think the last sentence is a little indefinite. It says, "Twisted or badly hewn ties must not be notched, but the bearings must be made true with the adze." I suppose what is intended is that ties shall be hewn so that there is a good surface, instead of there being a mere notch. It seems to me the reading could be improved a little, to bring out the real meaning, for even a notch may have the surface true, which evidently is not what is intended. It might be made to read, "Twisted or badly hewn ties must not be notched, but must be hewn for the full length of the tie," or words to that effect.

Mr. F. D. Anthony:—The intention of the Committee is that they shall be properly adzed, but not notched—it is a question of forming the surface. What would you suggest as a change?

Mr. E. R. Lewis (Michigan Central):—I assume we all realize the immense importance of the proper method of laying ties. The first sentence of Rule 14 reads: "The heart side of ties must be turned down." So far as I know, this is a dogma of railway rule books; a positive order, leaving absolutely nothing to the judgment of the practical trackman who has been laying ties for fifty years. This rule most vitally concerns the whole track structure, the very foundation of it. It affects the construction and maintenance of all railways.

I opposed this rule in the Rules Committee of my own road and I oppose it here, because I believe it is wrong and I believe it impossible of successful application. I am rather curious to know its origin. I would like to ask the Committee why a tie should not be laid heart side up.

In the actual manual labor of laying track, in the direct charge of maintenance and construction work, I have had this problem pretty close in front of me for over twenty years, and I presume others have had more experience. I have studied it from all angles, and I have investigated many hundreds of thousands of ties with this very point in view. I am aware that this rule is contained in the Rule Books of a great many of the best railways in this country. So much the worse for the Rule Books. They are wrong. The tracks of these very roads, whose Rule Books contain this rule, are not laid in accordance therewith. I make this statement without fear of contradiction, because I know it to be impossible, because I know that these roads have their ties not so laid. What is the tie for? This definition is taken from the Manual of this Association: "The tie is that transverse member of a railway track which supports the rails and by means of which the rails are retained in position." The purposes mentioned in this definition cannot be best served by placing the tie heart side down. The heartwood of the tie is denser than the sapwood. Its cell walls are thicker and the cells contain less moisture when the wood is green. Therefore it loses less moisture when the wood is seasoning. The cell walls of the sapwood are thinner

than the cell walls of the hardwood, the cells are larger; the sapwood is not so dense, and cannot hold the spike as well. With the sap side up, you get only the point of the spike into the densest wood. In the less dense sapwood the neck of the spike has a tendency to work out of gage and give way a little more than does the point. What is especially necessary is to get the neck of the spike, that part of the spike nearest to the rail, where it will do the most good and hold the gage best. When any timber starts to check, it checks from the sap side first; because the sapwood loses sap first, loses more of it, and allows shrinkage to take place more quickly, also it shrinks more than the heartwood. The heartwood being denser contains less moisture and absorbing less moisture is longer lived than the sapwood. The sapwood will dry out, check and warp away from the heart side of the stick. This applies to all sorts of timber as any timberman will agree. In the town where I reside we cut something like two hundred million feet of timber every year. Every lumberman in the Saginaw Valley has agreed with me that timber will warp away from the heart; every lumberman in every other valley will tell you the same thing. Therefore I say that the tie should be laid heart side up, because any shrinking and warping of the tie is away from the heart side. Therefore the heart side is the convex side. Now, you cannot get a good bearing for a tie unless you lay it with the convex side up. If you lay it with the concave side up you are working against the law of gravity, and you obtain a rocking chair effect instead of a stable foundation for a railway.

Ask any good, practical laborer how to lay a tie and he will tell you "belly up." This is the trackman's rule the world over. I estimate that 90 per cent. of the ties that are laid in track are perceptibly warped or crooked. They are not precisely straight. There is a choice of bearing. I do not think any track foreman ever should allow a tie to be put in the track without choosing the bearing, the side which should go up. Irrespective of sap side or heart side, he must get the convex side up.

According to the Government's statistics, about 80 per cent. of the 125,000,000 ties bought by the railways of the United States in 1911 were hewn ties. This hewn tie is a pole tie. A man going into the business of making ties is not going to pick out timber which has to be split and worked out on four sides. He picks out pole timber that requires working on only two sides. The other timber is worked up into something else more valuable to him. Sawed ties are manufactured from large logs; all the boards possible being sawed from four sides of the stick, leaving a box heart tie. You cannot put the heart side of such a tie up or the heart side down. The heartwood is in the center. The same is true of the pole tie.

Besides being wrong in principle, I believe this first sentence of Rule 14 is unnecessary. In only 5 or 10 per cent. of the ties is the heartwood on one side. Even that 5 or 10 per cent. we should not lay wrong side up. In the past, when we used untreated ties, most of them failed us through decay. In the future, with the creosoted tie, it will be the other way.

We will lose our ties through wear, and we want the best wearing wood where it will do the most good. We want the heart side where it will do the most good. Put it where it will give the greatest amount of wear.

There is one best way of doing everything. There is only one best way of laying a tie and that is to lay it the best way. Why not say so? To this end I move that this part of Rule 14 be amended to read: "Ties must be laid so as to obtain the best bearing." We want the best railway, and we cannot get it unless we lay the ties convex side up.

Mr. Robert Ferriday (Cleveland, Cincinnati, Chicago & St. Louis):—I second the motion.

(The motion carried.)

Mr. L. S. Rose (Cleveland, Cincinnati, Chicago & St. Louis):—I ask why the rule is made to square the ends of the ties on double track on the outside.

Mr. F. D. Anthony:—My impression is that is a pretty general practice. That was the decision of the Committee, and I am personally not in a position to explain it.

The President:—Do you make any motion?

Mr. Rose:—I have not any motion to make. I know that is pretty common practice. I have seen some track laid where the ties were squared on the inside. There ought to be some reason for it. Personally I would square the ties on the inside on double track just for the looks of it.

The President:—The Acting Chairman of the Committee is unwilling to accept the suggestion, so unless some motion is made we will pass to Rule 15.

The Secretary:—"(15) Whenever spikes are drawn from ties, wooden tie plugs must be driven into all holes except in ties which are to be renewed that season. In replacing spikes they should be driven into the plugs."

Mr. L. A. Downs (Illinois Central):—I think we should make some reference to the use of treated plugs in treated ties.

The President:—Have you any suggestion for a complete sentence?

Mr. L. A. Downs:—Add to the present paragraph, "When spikes are withdrawn from treated ties, plugs of treated material should be used."

Mr. F. D. Anthony:—It seems to me that rule is general. It does not refer particularly to either treated or untreated ties. These rules may be supplemented by such special rules as local conditions may require. It seems to me this rule is general enough.

The Secretary:—"(16) In unloading rails from cars they should be skidded or otherwise carefully lowered to avoid injury. Where it is necessary to drop them, both ends must be dropped together and the greatest care taken to avoid their falling on hard and uneven surfaces."

Mr. E. R. Lewis:—In the interest of brevity, I would move that the last sentence of Rule 16 be eliminated. I understand that it is put in there for emphasis, but there is emphasis in brevity. I think if we say: "In unloading rails from cars they should be skidded or otherwise carefully lowered to avoid injury," we have said all that is necessary.

Mr. L. A. Downs:—I second the motion in the interest of good practice and not for the sake of brevity.

Mr. H. T. Porter (Bessemer & Lake Erie):—As I understand it, the second sentence is provided for those cases where they have not the equipment to carefully lower the rails. On a sandy roadbed, with reasonable care, you can drop the rails without danger of breaking, and I would judge that a very large percentage of the rails in this country are unloaded without their being skidded or lowered carefully with some device.

Mr. E. R. Lewis:—I think the first sentence covers that point. If you carefully drop them, you carefully lower them.

Mr. Ferriday:—I would suggest the word "unloaded" in place of "lowered."

The President:—There is a motion before the Association. It has been moved and seconded that the second sentence of Rule 16 be eliminated.

(A vote was taken on the motion and it was lost.)

The President:—Any further discussion?

Mr. F. D. Anthony:—Mr. Tratman's correction, striking out the word "new" in the first sentence, has been accepted.

The Secretary:—"(17) The bottom of the new rail and the bearing surface of the tie shall be cleaned before the new rail is laid.

"(18) When replacing rail with rail of the same section, only two rows of spikes shall be drawn; in replacing with rail of a different section, three rows of spikes shall be drawn.

"(19) In laying new rail, standard expansion shims shall be used. The temperature of the rail shall be taken by placing the thermometer on the rail. The openings between 33 ft. rails shall be in accordance with the table.

"The rail should be laid without bumping and, when practicable, laid rail by rail."

Mr. Ferriday:—If it is permissible, I would like to return to Rule 18. I do not think the rail section should determine whether two rows of spikes shall be left or three rows. It depends upon certain parts of the section. I know that in a great many cases but two rows of spikes are drawn, in laying rails of different sections, although the sections are quite different. It depends upon the gage of the track, and the difference in sections, that is, the width of the base and the width of the head. I would make a motion to add, after that paragraph, the words, "if necessary."

The President:—That is accepted by the Committee.

The Secretary:—"(20) The rails shall be brought squarely into line and at least two bolts tightened before spiking. All joint bars shall be securely fastened with the full number of bolts, tightening those at the center first. At permanent connections of rails of different sections step chairs and offset splices must be used."

Mr. Tratman:—I propose that after Rule 19 there should be added a

paragraph, giving the special requirements for expansion spacing in tunnels. The figures which are given in the table under Rule 19 are for open track. Some railways note on their tunnel plans that above a certain temperature all rails shall be laid close, but not bumped together. I think it would be well to insert a paragraph relating to spacing in tunnels and, possibly, on long bridges, where expansion joints have to be considered.

Mr. F. D. Anthony:—I think the Committee had in mind that this would come under the head of special rules to govern local conditions. However, if the convention wants to insert that rule, I would like to hear it discussed.

The President:—Any discussion? The Committee does not feel like accepting that paragraph, unless there is a motion adopted by the Association.

Mr. Tratman:—In Rule 20 the terms "step chairs" and "offset splices" are used. Then in Rule 22 the term "compromise joints" is used. Those are three names for one device, and I think in Rule 20 the words "compromise joints" should be used.

Mr. F. D. Anthony:—Do you mean in place of offset joints?

The President:—Do you mean "compromise" instead of "offset?"

Mr. Tratman:—Either use the two or change it. I would move that "offset splices" be changed to "compromise joints."

The President:—The Committee will accept "compromise splices."

The Secretary:—"(21) All spikes must be driven vertically with the face in contact with the base of the rail. They should not be straightened while being driven. The rail must be full spiked and the spikes staggered so that the outside spikes shall be on the same side of the tie and the inside spikes on the opposite side.

"(22) In making temporary connections in main tracks an old rail should be cut and fastened to the new rail, using compromise joints when necessary. Switch points shall be used for this purpose only during the presence of the Track Foreman."

Mr. L. A. Downs:—I move that we eliminate the last sentence.

(Motion seconded and carried.)

The Secretary:—"(23) After new rail is laid the track must be lined and surfaced.

"(24) All kinked or crooked rails must be straightened before being laid; if bent in service they must either be removed or straightened."

Mr. A. S. Baldwin (Illinois Central):—This says, "If bent in service they must either be removed or straightened." After straightening, I think it is unsafe to lay them back in the main track.

Mr. F. D. Anthony:—This does not say they shall be laid back in the main track. It may be laid in a siding.

Mr. A. S. Baldwin:—The presumption from the context is that that is what is referred to.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—Does it necessarily mean that a rail is unsafe because it has been straightened? Do I understand Mr. Baldwin to mean that? If that is true, the curv-

ing of rails is bad practice. I recall having straightened as many as 2,000 rails, some of which are still in service to-day, and that was twenty years ago.

Mr. A. S. Baldwin:—It is true that the curving of a rail is, in a measure, the bending of it. Of course, by the roller rail bender, so-called, it is a very gradual process, and I have seen cases where surface bent rails in the main track were taken out and straightened and then relaid in the main track, and I found they were liable to breakage at the point where the straightening had been done, and I have known of quite a number of cases where they did break at that point. From the nature of steel, it seems to me it is not a safe practice to take a surface bent rail and straighten it and put it back into the main track, under very high, heavy service.

Mr. H. T. Porter:—A surface-bent rail means a rail that is bent vertically. Any power that is sufficient to bend it, is liable to damage the structure of the rail, but a rail can be bent sideways or horizontally because, on account of the section, it is not so stiff in that direction. So it can be bent sideways and horizontally and straightened again and put back in the track again without taking any great chances. I do not think this is intended to refer to surface-bent rail, but that it means rails bent out of line.

The President:—Any further discussion? There is no motion before the house.

Mr. C. C. Wentworth (Norfolk & Western):—I merely want to call attention to the fact that switch points are bent cold almost invariably before they are planed, and we do not find them breaking.

Mr. C. A. Morse (Santa Fe):—It seems to me these rules are rather too general for a railway, for the reason that we have first, second, third and fourth class track. We build light branches for the development of a country and take most anything and lay it there. To make a rule that you cannot straighten a bent rail is impracticable, because none of us follow it.

Mr. A. S. Baldwin:—I think after a rail has been bent that is kinked, as referred to in the first part of this rule, and then straightened, it should be treated as if it were a second-quality rail. After we get from the mills a new second-quality rail, it does not come up to the first-class specifications and we use it for switch leads in points of main line where there is no very high speed, and other places like that, and after a rail has been kinked I think it should be treated as a second-quality rail, and be put to the same uses as a second-quality rail.

Mr. E. R. Lewis:—I move that Rule 24, as printed in Bulletin 141, be adopted.

(Motion seconded and carried by a rising vote, resulting as follows: For, 41; opposed, 24.)

The Secretary:—"(25) Rails for curves of 2 degrees and over should be curved before being laid. In curving or straightening rails, the rail bender must be used."

Mr. S. A. Jordan (Baltimore & Ohio) :—I would like to ask the members of the Committee what kind of a rail bender they would use in curving the rail for a 2-degree curve and get anything like a uniform curve in the rail.

Mr. F. D. Anthony:—Do you mean what style of machinery?

The President:—The Committee says it is unable to answer that question.

Mr. H. E. Hale (Missouri Pacific) :—I move that it be changed to read 4 degrees instead of 2.

Mr. C. A. Morse:—The rule says that the rail bender must be used. I understand there are some roads in the country that have not been using a rail bender on the outside rail. They curve the inside rail and then spring the outside rail to gage with it. We have done that in a few cases on our road, and have found it very satisfactory, rather tending to get away from the short kinks that are there, whether you can see them or not, when the rail bender is used.

(The motion was carried.)

Mr. McDonald:—May I ask the Chairman whether the Manual shows whether any action has been taken on this matter in the past? I think it has already been fixed at 2 degrees.

The President:—A hasty examination of the Manual does not show any action to have been taken, but the Chair rules this will be a matter for the editor of the Manual to take care of when the time comes to print this. Rule 25 has, therefore, been changed to read "4 degrees" instead of "2," unless there is a division requested.

Mr. John G. Sullivan (Canadian Pacific) :—The word *the* is a definite article, and it would lead one to believe that the Committee had a special kind or make in mind. I would suggest *a* rail bender.

The President:—The Committee accepts that.

The Secretary:—"(26) When surfacing (picking up low joints or other low places), the general level of the track must not be disturbed."

Mr. J. B. Berry (Chicago, Rock Island & Pacific) :—I move to strike out everything in the parenthesis. There cannot be two different kinds of low joints. Surfacing means picking up the track, and it is covered by the balance of the rule.

The President:—The Committee accepts that. The rules are now open for a motion to adopt them as a whole as amended.

Mr. C. A. Morse:—Before doing that, there is a question on Rule 26, as amended by Mr. Berry. It would read, "When surfacing, the general level of the track must not be disturbed." I think that is misleading. If you are surfacing to a face, you certainly have got to disturb the surface of the track and any track has got to be surfaced to a face occasionally.

The President:—Do you wish to move to put those words back?

Mr. C. A. Morse:—Not exactly those words.

The President:—The words were eliminated by consent of the Committee and not by vote; therefore, it is subject to amendment, if you wish.

Mr. W. M. Camp (Railway and Engineering Review):—Does not Rule 4, on reballasting, cover that point?

Mr. H. T. Porter:—I would like to offer an amendment to Rule 26, as follows: "When picking up low joints or other low places, the general level of the track must not be disturbed." The word "surfacing" is a general term and applies to lifting track, when you are simply lifting one side or lifting joints, or when you are lifting up a foot in order to put in new ballast; so that "surfacing" is the general term; whereas, as I read it, this clause is to warn the foreman that, when he is simply picking up low joints and other low places, they must not disturb the general surface of the track. Now, that is a source of a great deal of difficulty on track maintenance. Old, experienced foremen can often go through a section, in the spring and early summer, and put it in first-class shape with little or no effort, whereas I have seen a young foreman, when it was only necessary to pick up his joints at low places, do more harm to the track than he did good by attempting to do what this rule says he must not do, namely, not disturb the general level of the track.

Mr. C. H. Stein (Central Railroad of New Jersey):—I would like to call attention to the fact that this reads, "when picking up low points"—a typographical error, no doubt. I think this would read better, "when picking up joints or other low places, the general level of the track must not be disturbed," and not duplicate the word "low," because that is very clear by inference.

Mr. H. T. Porter:—I accept that.

Mr. G. W. Merrell (Norfolk & Western):—I would like to ask if the word "maintained" would not be better—"the general level of the track shall be maintained?"

Mr. C. H. Ewing (Atlantic City Railway):—I hope the motion will not carry. I think all of us know that surfacing simply covers picking up low joints and low spots. Raising track is an entirely different proposition; so that the rule as agreed to by the Committee should stand.

Mr. Camp:—I think it is a little unfortunate that those words "picking up low joints and other low places" were eliminated because they explain what the Committee meant by the word "surfacing."

I am heartily in accord with this paragraph, because I do not believe that track should be raised out of face unless grade stakes be set for the lift, and that is provided for in Rule 4. I agree with Mr. Porter when he says that a great deal of injury to track is done by raising it entirely out of face when really all that is needed is to pick up the low spots. On this point the paragraph in question is important.

Were those words stricken out by motion?

The President:—They were stricken out by the Committee itself on suggestion of a member of the house.

Mr. E. T. Reisler (Lehigh Valley):—I would like to ask the intention of the Committee, in case bringing up a low joint does not make the track level.

The President:—Any further discussion on the motion? The motion is to change Rule 26 to read, "When picking up joints or other low places, the general level of the track must not be disturbed."

(Motion carried.)

The President:—The Instructions as amended now stand for action by the convention and I desire to read the rules for the consideration of reports.

(The President read the same.)

What is the pleasure of the convention in regard to these Instructions?

(A motion was made to adopt the Instructions as amended.)

Mr. Edwin F. Wendt (Pittsburgh & Lake Erie):—I desire to offer a statement respecting Rule 24 before this motion passes. Every rule under the head of "Rail," on page 67, seems to refer to the laying of new rails for the first time. In Rule 24 the second paragraph refers to rails bent in service. Therefore, it seems to me that Rule 24 should be divided into two sections. The first section relates to new rails being laid for the first time and the second section refers to rails which have already been in use and have become bent. I think we are a little inconsistent in mixing up rails bent in service with rails which have not yet been in the track; and, furthermore, I do not like Rule 24, especially in its relation to the attitude of public bodies, such as railroad commissions and courts of law, with respect to what is called "kinked" rails. I would like to ask the Committee if they will eliminate the second section of Rule 24, which refers to rails which have been in service and bent, either by reason of imperfectly balanced locomotives, or from some other cause—omit that entirely and allow the first section of the Rule to be consistent with the others? And if the Committee will accept that, I would like them to eliminate the word "crooked" and let it read "kinked rails must be straightened before being laid."

Mr. H. T. Porter:—It seems to me that all these rules, from 16 to 26, apply to laying rails, whether new or relaying rails. As far as Rule 24 is concerned, I would be very glad to see that word "crooked" eliminated. The rest of it I would like to see remain.

The President:—The Chair will have to rule that that is not strictly in accordance with the discussion on the motion as it is now put. There has been no second to either suggestion so far.

Mr. H. S. Wilgus (Pittsburg, Shawmut & Northern):—If it is not too late, I would like to refer to Rule 25. It seems to me that the Rule refers to the construction of entirely new track. It does not apply to rail replacement, and it seems that a sentence may be added, reading like this: "However, for renewals it will not be necessary to curve the rail; it may be sprung into place."

The President:—The Chair thinks it is out of order to amend any particular Rule now, in view of the fact that this motion for adoption has been put.

Mr. Stein:—It seems to me that these paragraphs 16 to 26, inclusive, refer to the laying of new rail and not the renewal of rail with other second-hand rail; that the title of these paragraphs should be changed and it should specify new rail instead of simply "rail." It appears to me as if there is confusion in those various classes, and that confusion seems to have carried itself through the minds of the Committee, because they appear to have had in mind, in clause 24, that it might be a replacement of rail in the track with other second-hand rail. I think the title should be "new rail," if this refers to new rail.

The President:—The question is demanded.

(A vote was then taken and the motion was carried.)

The President:—The Committee is dismissed with the thanks of the Association.

DISCUSSION ON SIGNALS AND INTERLOCKING.

(For Report, see pp. 69-76.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON SIGNALS AND INTERLOCKING.

L. R. CLAUSEN.	HUNTER MCDONALD.
W. H. ELLIOTT.	L. S. ROSE.

The President:—The next report is that of the Committee on Signals and Interlocking, of which Mr. A. H. Rudd is Chairman. In the absence of the Chairman, Mr. L. R. Clausen, the Vice-Chairman, will present the report.

Mr. L. R. Clausen (Chicago, Milwaukee & St. Paul):—The Committee on Signals and Interlocking was assigned four subjects, which appear on page 69. The Committee has no report on subjects 2, 3 and 4. The Committee has a report on subject 1, and they have also submitted a revised table of insulation resistances for rubber-covered wires. The table of insulation resistances is changed as the result of investigations of the Committee of the Railway Signal Association and was submitted to that Association at its annual meeting in October last, and by vote of the convention the table of insulation resistances was submitted to letter ballot and approved. The changes are comparatively slight and in order to make the American Railway Engineering Association specifications conform to the Railway Signal Association specifications, the Committee would desire to have this revised table approved by this Association. I make a motion to the effect that the revised table of insulation resistances shown on page 70 be adopted by this Association.

Mr. W. H. Elliott (New York Central & Hudson River):—I second the motion.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—I move that the table of insulation resistances be adopted in accordance with Rule 16-g, as provided in the General Rules.

Mr. Clausen:—We accept the amendment.

The President:—The motion is that this revised table be adopted for publication in the Manual.

(The motion was carried.)

Mr. Clausen:—The adoption of the table of insulation resistances carries with it the approval of the same table for the specifications of cables, both braided and lead-covered, which are covered by conclusions 2 and 3, at the top of page 70. I would, therefore, as representing the Committee, move the adoption of this same table, to be included in the

specifications for mineral matter, rubber-compound insulated, braided cables, and also for rubber-compound insulated lead-covered cables, as covered by conclusions 2 and 3.

(The motion was carried.)

Mr. Clausen:—The instructions to the Committee, No. 1, are as follows: "Continue investigation of outline and description of a comprehensive and uniform signal system, suitable for general adoption, conferring with proper committee of the American Railway Association." A report of the Signal Practice Committee of the Railway Signal Association has been submitted to the Railway Signal Association and has been rejected by that Association. In view of that fact the Committee presents the report which is found on pages 71-4, as information. I move that the report as indicated on these pages be received as information.

(The motion was carried.)

Mr. L. S. Rose (Cleveland, Cincinnati, Chicago & St. Louis):—I move that the report on pages 75-6 be received as information.

Mr. Clausen:—I failed to cover the entire report; the motion should have included pages 75-6.

The President:—The Chair will accept that, without any motion, that it includes the minority report also.

The Committee is dismissed with the thanks of the Association.

DISCUSSION ON IRON AND STEEL STRUCTURES.

(For Report, see pp. 81-88.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON IRON AND STEEL STRUCTURES.

F. J. Bachelder.
A. S. Baldwin.
E. C. Brown.
J. L. Campbell.
C. H. Cartlidge.
Thomas Earle.
E. A. Frink.
J. M. Meade.
H. T. Porter.
Albert Reichmann.
O. E. Selby.
John G. Sullivan.
Edwin F. Wendt.

The President:—The next report is that of the Committee on Iron and Steel Structures, of which Mr. C. H. Cartlidge is Chairman. We will ask the Chairman of the Committee to make the opening statement.

Mr. C. H. Cartlidge (Chicago, Burlington & Quincy):—Your Committee reports on the following subjects:

Subject No. 1—Investigation on Impact and Secondary Stresses: Appendix B contains a report from Prof F. E. Turneaure, Chairman of Sub-Committee on Impact, giving an outline of the work done by the Committee during the past year.

Subject No. 2—Influence of Theory, Experiment and Experience on Bridge Design: It was unanimously decided by the Committee that it was unable to report adequately on this subject, and the request is therefore made that the subject be dropped.

Subject No. 3—Rules for Instruction and Guidance of Inspectors in Mills, Shop and Field: The Committee reports progress. The Chairman of the Sub-Committee has received discussion from two of the members of his Sub-Committee, and will probably be able to submit a paper giving the results of their findings during the next few months.

Subject No. 4—Design of Built-up Columns: The tender of the services of this Committee to collaborate with the Joint Committee of the American Society of Civil Engineers was made and very promptly accepted. Sufficient time has not yet elapsed to permit the organization of any actual work on this subject. The program proposed by the American Society of Civil Engineers Committee is very elaborate and comprehensive and when carried out will immensely increase our knowledge of the subject. In order that this Committee do any practical work on this subject, it will be necessary to have funds. Your Committee understands, of course, that none of the funds of the Association are available for this purpose. We feel warranted, however, in recommending that individual roads be asked to contribute for the purpose of

making these tests. This work and that of the Impact Committee are original research work and it is hardly necessary for us to point out the ultimate value of the work done in the manner in which it has been done. It will probably be necessary in the near future to take cognizance of these experiments in our specifications for design, but the Committee does not recommend that any change be made at present, nor until further experiments on secondary stresses have been made, and if possible, considerable work on columns. The Committee will present later a more definite report of the probable amount of money needed for the first year's work. It is expected that this will be very small and that it can easily be raised.

Subject No. 5—Specifications for Erection of Steel Bridges: The Committee presents for the consideration of the Association a set of specifications, revised in accordance with the discussion at the last convention and with the written discussions from members and others received since the convention.

The recommendations of the Committee are as follows:

(1) That the specifications for Bridge Erection be adopted and printed in the Manual.

(2) That the report of the Impact Committee be received as information.

(3) That no change be made at present in the specifications for steel railway bridges printed in the Manual.

I move the adoption of the specifications for the erection of railroad bridges printed in Appendix A.

The President:—We will read each one of these sections contained in Appendix A, as was done in the previous case.

The Secretary:—"1. The Contractor shall erect, rivet and adjust all metal work in place complete, and perform all other work hereinafter specified.

"2. The Contractor shall provide all tools, machinery and appliances necessary for the expeditious handling of the work, including drift pins and fitting up bolts.

"3. The method of erection and plans for falsework and erection equipment shall be subject to approval by the Engineer, but such approval shall not relieve the Contractor from any responsibility. Falsework will be built by *..... Falsework material of every character will be provided by the *.....

"The temporary structure for use during erection and for maintaining the traffic shall be properly designed and substantially constructed for the loads which will come upon it. All bents shall be thoroughly secured against movement, both transversely and longitudinally. The bents shall be well secured against settling, and piles used wherever firm bottom cannot be obtained. Upon completion of the erection, the temporary structure, if the property of the Railway Company, shall be removed without unnecessary damage, and neatly piled near the site or

loaded on cars, as may be directed. If the property of the Contractor, it shall be removed in a manner subject to the approval of the Engineer.

"Falsework placed by the Railway Company under an old structure or for carrying traffic may be used as far as practicable by the Contractor during erection, but it shall not be unnecessarily cut or wasted."

Mr. A. S. Baldwin (Illinois Central) :—I would ask the object of the third clause of Section 3, which provides that "Falsework placed by the Railway Company under an old structure or for carrying traffic may be used as far as practicable by the Contractor during erection, but it shall not be unnecessarily cut or wasted." That, it seems to me, is a special case, and does not apply here. You cannot make a rule of that kind to apply to all cases. I would suggest the elimination of that clause. You have already provided for the falsework in the first paragraph of the section, and here comes a modifying clause which might cause complication, and I think it should be a case for special arrangement between the Contractor and the railway at the time the contract was made.

I move that the third paragraph of clause 3 be eliminated.

Mr. H. T. Porter (Bessemer & Lake Erie) :—It is not an uncommon thing to put bents under a truss that has become light. I had a case where I had to do that, so I took up the question with a bridge company as to a plan of falsework which could be used in the erection of a new structure. They put the falsework under our old bridge and used it when they came to erect a new bridge.

Then in another case, where the old bridge was wrecked by a washout and an engine going onto it, we had to build a trestle across the river in order to keep the traffic open, so we built our trestle over the river, and it was used for falsework by the Contractor in erecting a truss. This is a specification for erection, and I call your attention to the fact that this covers cases that do happen in ordinary experience, and I see no objection to leaving it in here. It simply makes the specification more complete.

Mr. A. S. Baldwin:—The trouble is there are no two cases that will be alike, in all probability, and consequently it cannot be covered by a general rule. I think it is well to call attention to matters like that, and I suggest the following modification—

The President:—There is a motion now before the house to eliminate the paragraph.

Mr. A. S. Baldwin:—I withdraw the motion.

(Seconder agreed, and the motion was withdrawn.)

Mr. A. S. Baldwin:—I make a motion that this clause be modified as follows: "If falsework has been placed by the Railway Company under an old structure, or for carrying traffic, the use of it by the Contractor must be subject to a special arrangement, to be made with the engineer of the Railway Company."

Mr. O. E. Selby (Cleveland, Cincinnati, Chicago & St. Louis):—I think that the clause as it stands does not represent a special case, but a very usual case. It frequently happens that falsework has been placed under a bridge for the purpose of strengthening a weak bridge, to enable it to carry the traffic, and it would be unwise to throw it away and not take advantage of it for erection purposes.

I do not see how it would lead to complications with the Contractor, because it represents an existing condition at the time bids are asked for and the contract is let. If the falsework is there, it is there when the bidder examines the job, and he is expected to examine the job and take note of all the existing conditions. I think that the existence of that falsework should be taken cognizance of, and the way it is put in the specifications here does that in a satisfactory manner.

Mr. J. M. Meade (Santa Fe):—I wish to say that the Santa Fe has done a great deal of work, almost exactly as outlined in this report, and I strongly endorse what Mr. Porter says. I believe we should leave that paragraph in the specifications as written.

Mr. Cartlidge:—In making these specifications we desired to adapt them as widely as possible to any conditions which are to be met with. It is possible, of course, that we have tried to cover some conditions which are not so nearly universal as some of the others covered. On the other hand, it seems to the Committee that any clause such as this, which may not meet with the approval of the Engineer or the Railway Company letting the contract, can be eliminated in the draft of the contract made at the time the work is let. These specifications are not intended to be used verbatim, but as a model or guide for drawing up specifications. With that explanation of the purpose of the specifications, we think that some of the clauses may be allowed to stand as being suggestions for practice, rather than clauses which must be incorporated in all contracts.

Mr. A. S. Baldwin:—I think the members have misunderstood the object that I had in view in making this motion. It is not that the falsework should not be used; it is, of course, in the line of economy that anything that is existent on the railway should be used; but I wanted to have the clause so worded that the Railway Company would be sure to get proper credit for it. Take a case in which a Railway Company is about to let a contract for the erection of all its bridges for a year. The Contractor, in figuring for these bridges, would figure on the falsework for all of the bridges; then, at any point where he found falsework, there would be that much net gain to him to which he was not entitled, whereas, if the provision is made in the way I have proposed where the Contractor comes to a bridge for which the falsework has been provided, it becomes necessary for him to make a special arrangement for that bridge with the Railway Company and the Railway Company gets credit for the material put in.

Mr. Porter:—If this clause is left in the specification, then it does

not have to be handled as a special matter, and if a railway is letting a contract for all of its bridges for a year, and takes competing bids, if this clause is in the specification, the chances are that some of these contractors, at least, will take this into consideration, in making their bids, and the Railway Company would get a lower bid than if this clause is left out. If the clause is left out of the general specification, the Engineer may omit to take it into consideration when he calls for bids, so I think it is the proper place for it and it should remain.

Mr. F. J. Bachelder (Baltimore & Ohio):—This clause seems to be covered in the forepart of the section. It says: "The method of erection and plans for falsework and erection equipment shall be subject to approval by the Engineer, but such approval shall not relieve the Contractor from any responsibility. Falsework will be built by *..... Falsework material of every character will be provided by the *....." That, it seems to me, covers these particular cases, and we could eliminate the latter clause.

(The motion was lost.)

The Secretary:—"4. The work shall be prosecuted with sufficient force, plant and equipment to expedite its completion to the utmost extent and in such a manner as to be at all times subordinate to the use of the tracks by the Railway Company, and so as not to interfere with the work of other contractors or to close or obstruct any thoroughfare by land or water, except under proper authority.

"Reasonable reduction of speed will be allowed upon request of the Contractor.

"Tracks shall not be cut nor shall trains be subjected to any stoppage except when specifically authorized by the Engineer.

"The Contractor shall protect traffic and his work by flagmen furnished by and at the expense of the Railway Company. The Contractor shall provide competent watchmen to guard the work and material against injury."

Mr. E. A. Frink (Seaboard Air Line):—The second paragraph of this section reads: "Reasonable reduction of speed will be allowed upon request of the Contractor." That means that upon the request of the Contractor the Railway Company will issue a "slow order" limiting the speed over the structure to a certain degree. I think there should be a clause added specifying that the Railway Company will not be responsible for any injury to the property or structure of the Contractor, due to failure on the part of the Railway Company to carry out the "slow order." I say that for this reason: In one case in our experience on the Seaboard Air Line we had a "slow order" over the structure and the Contractor was engaged in building a cofferdam which he tied up to the structure. Some of the trains over the structure exceeded the speed limit and the Contractor thereupon set

up a claim, which he substantiated in court, that the Seaboard Air Line was responsible for the damage to his work because it did not maintain the slow order. Therefore, Mr. Chairman, I move to amend that paragraph by adding: "The Railway will not thereby in any way incur any responsibility for damage to the work or materials of the Contractor for failure to maintain such reduction in speed."

Mr. Thomas Earle (Pennsylvania Steel Company):—It seems to me that the addition of this clause would nullify the balance of the paragraph. What is the advantage of a slow order to a Contractor if he knows beforehand that he is not to expect that slow order to be fulfilled, and in addition if there is a slow order of thirty miles an hour and a train goes through at sixty miles an hour and the Contractor's plant is destroyed and he has to pay for it, of what benefit is the clause to him? It will add a burden on the Contractor, but in the end the Railway Company will pay for all such clauses, because the Contractor must eventually be reimbursed for all such expenses by his customers, who, in this particular case, are the railways.

Mr. J. L. Campbell (El Paso & Southwestern):—I agree with the remarks of the speaker who has just preceded me. I do not think we can enforce a clause of that kind. I do not believe that you can release a Railway Company from proper responsibility by the insertion of such a clause, and I believe it would impair the force and effectiveness and dignity of the work of this Association to put such a clause as that in the specification.

Mr. F. J. Bachelder:—This clause does not specify the speed restriction which is to be placed on the structure. It simply provides for a reasonable reduction of speed. I think the clause should stand as written.

Mr. Frink:—It is true that this clause does not specify the speed limit, but when you, at the request of the Contractor, do lower your speed, then you have to specify that speed limit. If the Contractor asks for a reduction of speed, you ask the operating department to put on a reduction, and then you have fixed the speed limit.

In answer to Mr. Campbell, I will say it is like this—if you put a four-mile slow order on the train, and some trains go through at eight miles per hour, if the Contractor can bring witnesses to testify that the train passed over the structure at eight miles per hour and his work was injured, then you are liable. It does not require a speed of sixty miles an hour; it does not require a speed of more than six miles an hour. It is simply a question of whether the Contractor can get witnesses to testify that the speed of the train was greater than the limit of the slow order and injured his work. This may in some cases impose a hardship on the Contractor, but I think if you do not put it in it may in more cases impose a hardship on the Railway Company.

Mr. Albert Reichmann (Resident Engineer, American Bridge Company):—I think the words, "reasonable reduction of speed will be allowed," are sufficient. In my opinion the word "reasonable" takes care of that.

Mr. John G. Sullivan (Canadian Pacific):—The trouble with this clause is this—that in case the Contractor asks for a certain speed and the speed is exceeded, if anything happens, the Contractor will endeavor to make the Railway Company responsible. Would it not be better to say "a reasonable reduction of speed will be allowed on the recommendation of the company's Engineer?" Leave it in the hands of the Engineer, rather than the Contractor. He is responsible merely for the work, and if the structure is going to fail by running trains at sixty miles an hour he is not going to allow it.

Mr. C. H. Stein (Central Railroad of New Jersey):—I favor the clause just as it reads. I believe the point that has been raised is practically covered by a succeeding paragraph which reads: "The Contractor shall protect traffic and his work by flagmen furnished by and at the expense of the Railway Company." It is the business of the Contractor to see that these flagmen carry out their instructions and hold the speed of the trains down to the limit placed on them by the Engineer in charge and the operating department, so that I do not think it is necessary to introduce any additional clause in these specifications.

Mr. Porter:—I offer an amendment to read as follows: "Reasonable reduction of speed, upon request of Contractor, can be provided for in the contract."

The President:—That is so different from the amendment already proposed that it cannot be received.

Mr. Porter:—The point I want to make is that in some contracts you do not want any reduction of speed whatever, and you may require the Contractor to take out the old bridge and put in a new bridge, in between trains, without either stopping or delaying the trains. This being a general specification, the contract let under this specification entitles the Contractor to a reasonable reduction of speed if he should so request.

(The motion was lost.)

Mr. E. C. Brown (Carnegie Steel Company):—Is it not a fact that some railway companies do not admit of any reduction whatever in the speed? It seems to me that this clause should take cognizance of that fact.

Mr. Cartlidge:—I have practically the same answer to make to Mr. Brown as I made to Mr. Baldwin, that the specification attempts to cover all cases, and such clauses as apply to particular cases, which are not required at the time of letting the contract, may be very readily eliminated.

The Secretary:—"5. If, under the contract, work train or engine service is furnished the Contractor free of charge, such service shall consist only in unloading materials and in transferring the same from a convenient siding to the bridge site. Other engine service shall be paid for by the Contractor at the rate of $..... per day per engine, the time to include the time necessary for the engine to come from and return to its terminal. When engine service is desired, the Contractor shall give the proper railway officials at least 24 hours' advance notice and the Railway Company will furnish the service as promptly as possible, consistent with railroad operations.

"When derrick cars are used on main tracks, their movements shall be in charge of a train crew, and the expense of the crew and any engine service other than as noted above shall be charged to the Contractor."

Mr. A. S. Baldwin:—I think it is good practice to require the Contractor to pay part of the cost of the work train service. Where the full expense of the work train service is paid for by the Railway Company, the contractors call for work trains where they could be avoided and are negligent in letting them go, and I have made it a practice to give a price for the service of the work train per day that will about divide the cost between the Railway Company and the Contractor.

Mr. Cartlidge:—The Committee spent more time over that clause than any other in the specification. It is a very difficult one to cover. The practice is very widely variant on different roads, and we have this further point to consider: In making a specification, if the specification does not set forth the conditions under which the Contractor must make his bid, he is likely to add something for good measure to cover the question at issue; in other words, if he has an indefinite amount of train service to pay for, he will put in his estimate a flat price sufficient to cover all that he will have to pay, and it is necessary in a general specification either to put all of it at the expense of the Railway Company or all of it at the Contractor's expense. It will be very easy to amend these specifications for particular cases, but it would be very difficult so to word them as to provide for all cases which may arise in practice.

The Secretary:—"6. When transportation of equipment, materials and men is furnished free over the Railway Company's line, it shall be subject to such conditions as may be stated in the contract."

Mr. Edwin F. Wendt (Pittsburgh & Lake Erie):—I do not wish to oppose this section, but I rise to state that for some years our company followed the practice of furnishing free transportation for materials and work train service. There is so much difficulty in connection with this practice that we found it convenient to abolish it, and at the present time we compel all contractors to bid on just one condition, namely, the bid shall include all transportation of both men and materials and all cost of work train service. Where this practice

can be followed, the Engineer has a great deal less trouble in connection with his field work and his accounts, and I believe this is the practice to which we are rapidly tending in our country to-day.

The Secretary:—"7. The Railway Company will furnish all masonry to correct lines and elevations, and, unless otherwise stated in the contract, will make all changes in old masonry without unnecessarily impeding the operations of the Contractor. The Railway Company's engineers will establish lines and elevations and assume responsibility therefor, but the Contractor shall compare the elevations, distances, etc., shown on plans, with the masonry as actually constructed as far as practicable, before he assembles the steel. In case of discrepancy, he shall immediately notify the Engineer.

"8. Cars containing materials or plant shall be promptly unloaded upon delivery therefor, and in case of failure to do so the Contractor shall be liable for demurrage charges. Material shall be placed on skids above the ground, laid so as not to hold water, and stored and handled in such a manner as not to be injured or to interfere with railroad operations. The expense of repairing or replacing material damaged by rough handling shall be charged to the Contractor. The Contractor, while unloading and storing material, shall compare each piece with the shipping list and promptly report any shortage or injury discovered.

"9. When traffic is to be maintained it will be carried on in such a manner as to interfere as little as practicable with the work of the Contractor.

"Changes in the supporting structure or tracks required during erection shall be at all times under the direct control and supervision of the Railway Company."

The Secretary:—"10. Unless otherwise specified, metal work in the old structure shall be dismantled without unnecessary damage and loaded on cars or neatly piled at a site immediately adjacent to the tracks, and at a convenient grade for future handling, as may be directed. When the structure is to be used elsewhere, all parts will be matchmarked by the Railway Company; when the old bridge is composed of several spans the parts of each shall be kept separate.

"11. Material shall be handled without damage. Threads of all pins shall be protected by pilot and driving nuts while being driven in place.

"Light drifting will be permitted in order to draw the parts together, but drifting for the purpose of matching unfair holes will not be permitted. Unfair holes shall be reamed or drilled.

"Nuts on pins and on bolts remaining in the structure shall be effectively locked by checking the threads.

"All splices and field connections shall be securely bolted prior to riveting. When the parts are required to carry traffic, important connections, such as attachments of stringers and floor beams, shall have at least fifty (50) per cent. of the holes filled with bolts and twenty-five (25) per cent. with drift pins. All tension splices shall be riveted up

complete before blocking is removed. When not carrying traffic, at least thirty-three and one-third (33⅓) per cent. of the holes shall have bolts.

"Rivets in splices of compression members shall not be driven until the members shall have been subjected to full dead load stresses. Rivets shall be driven tight. No recupping or calking will be permitted. The heads shall be full and uniform in size and free from fins, concentric and in full contact with the metal. Heads shall be painted immediately after acceptance.

"Rivets shall be uniformly and thoroughly heated and no burnt rivets shall be driven. All defective rivets shall be promptly cut out and redriven. In removing rivets the surrounding metal shall not be injured; if necessary, the rivets shall be drilled out."

Mr. Earle:—The fourth paragraph of section 11 reads: "All splices and field connections shall be securely bolted prior to riveting. When the parts are required to carry traffic, important connections, such as attachments of stringers and floor beams, shall have at least fifty (50) per cent. of the holes filled with bolts and twenty-five (25) per cent. with drift pins." I think 50 per cent. with drift pins and 25 per cent. with bolts will give better results. Drift pins absolutely fill the holes, and if you have drift pins and bolts, both in the same splice, the drift pins will carry all the stresses, as they are the only ones actually in contact.

Mr. Cartlidge:—I think it is conceded that not all rivets fill all the holes and that a good many of our structures are being carried on friction.

Mr. Earle:—If the drift pins fill the hole, that is the first thing which will be affected. The hole is absolutely filled with the drift pin and the bolt cannot offer any frictional resistance until the drift pin begins to move.

Mr. Cartlidge:—The style of drift pins with which I am familiar are tapered and the largest diameter of the drift pin is the diameter of the rivet hole, and that diameter occurs in only one place in the length of the drift pin. It is a little difficult to see how such a pin can be any better than a bolt; that is, a tapered drift pin in a cylindrical hole.

Mr. Selby:—These specifications are intended to represent recommended practice, and to a great extent common practice, and I would ask Mr. Earle if he knows of it being common practice to use two-thirds drift pins and one-third bolts?

Mr. Earle:—That is practically the way we do work where we carry heavy traffic. It is seldom we have to carry heavy traffic on steel work of that kind, but, where we do, that is the way we do it, if it has the approval of the Engineer.

As far as the drift pin is concerned, quite a distance of the upper end of the drift pin is cylindrical, and it is always driven so far that the cylindrical part of the drift pin will be entirely in the hole.

Mr. Cartlidge:—It is the opinion of the Committee that it is diffi-

cult to insure that the cylindrical part of the drift pin shall coincide with the cylindrical part of the hole. But I will state that the opinion of the Committee is, as far as common practice goes, the bolts should be the larger proportion and the drift pins in the minority, and that this practice represents the better practice followed by the railways.

The Secretary:—"12. Correction of minor misfits, and a reasonable amount of reaming shall be considered as a legitimate part of the erection.

"Any error in shop work which prevents the proper assembling and fitting up of parts by the moderate use of drift pins, and a moderate amount of reaming and slight chipping or cutting shall be immediately reported to the Engineer and the work of correction done in the presence of the Engineer, who shall check the time expended.

"The Contractor shall render an itemized bill for such work of correction for the approval of the Engineer.

"13. Holes for all anchor bolts, except where bolts are built up with the masonry, shall be drilled by the Contractor after the metal is in place and the bolts shall be set in Portland cement grout.

"14. Bed plates resting on masonry shall be set level and have a full even bearing over their entire surface; this shall be attained by either the use of Portland cement grout or mortar, or by tightly ramming in rust cement under the bed plates after blocking them accurately in position.

"15. The *..... will frame and place the permanent timber deck.

"16. The paint will be furnished by *..... and shall be of such color, quality and manufacture as may be specified.

"Surfaces inaccessible after erection, such as bottoms of base plates, tops of stringers, etc., shall receive two coats of paint before assembling in place. After erection, the entire structure shall receive two coats of paint, allowing enough time between coats for the first coat to dry before applying the second. No paint shall be applied in wet or freezing weather, nor when the surface of the metal is damp. Painting shall be done in good and workmanlike manner, subject to strict inspection during progress and after completion, and in accordance with special instructions which shall be given by the Engineer. All metal shall be thoroughly cleaned of dirt, rust, loose scale, etc., before the paint is applied.

"17. The Contractor, after completion of the work of erection, shall remove all old material and debris resulting from his operations and place the premises in a neat condition.

"18. During the entire progress of the work the Contractor shall have a competent superintendent in personal charge and shall employ only skilled and competent workmen. Instructions given by the Engineer to the superintendent shall be carried out the same as if given to the Contractor. If any of the Contractor's employés by unseemly

*Insert "Railway Company" or "Contractor" as the case may be.

or boisterous conduct, or by incompetency or dishonesty, show unfitness for employment on the work, they shall, upon instructions from the Engineer, be discharged from the work, nor thereafter be employed upon it without the Engineer's consent.

"19. The work of erection shall at all times be subject to the inspection and acceptance of the Engineer.

"20. The Contractor shall assume all responsibility for loss or damage to his own work, materials or plant, due to any cause; also, for all loss or damage to the Railway Company's materials or property, and to other property adjacent to the railroad, due to causes within his reasonable control.

"The Contractor shall assume all responsibility for injury to the workmen and the public, or to any individual; and in case of accident or suit he shall defend the suit in person and relieve the Railway Company from all costs and expenses, and pay any judgments that may be recovered thereon.

"The Contractor shall comply with the laws and ordinances affecting the manner of doing work; shall take out all necessary permits and comply with their requirements, and shall take such precaution as may be necessary to protect life and property."

Mr. Cartlidge:—After talking this last section over with the Committee, I move the elimination of section 20 from the specification, as it is properly a clause of the contract and not of the specification.

(The motion was carried.)

The Secretary:—"21. The Contractor shall carry such liability insurance as is necessary to protect himself and the Railway Company against loss or damage caused by injuries to his men, and shall furnish the Railway Company a bond in form and of a surety acceptable to the Railway Company, providing for the faithful performance of the work and all matters pertaining thereto, in such sum as shall be specified in the contract."

Mr. Cartlidge:—The Committee wishes to move the elimination of section 21 also on the same ground.

(The motion was carried.)

The Secretary:—"22. The term "Engineer," as used herein, shall be understood to mean the Chief Engineer of the Railway Company, or his accredited representative."

The President:—These proposed specifications are now before you for action.

Mr. Wendt:—I move that these specifications be approved for publication in the Manual under "General Rule 16-g."

(The motion was carried.)

Mr. Cartlidge:—I move that the report of the Impact Committee be received as information.

(The motion was carried.)

The President:—The Committee is dismissed with the thanks of the Association.

DISCUSSION ON WOODEN BRIDGES AND TRESTLES.

(For Report, see pp. 77-80.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON WOODEN BRIDGES AND TRESTLES.

G. A. MOUNTAIN. C. C. WENTWORTH.

The President:—The report of the Committee on Wooden Bridges and Trestles will next be disposed of. Mr. C. C. Wentworth, the Chairman, will make the opening statement.

Mr. C. C. Wentworth (Norfolk & Western):—Mr. Chairman and gentlemen, the work assigned to the Committee last year was, first, to report on the formulas for use in determining the strength of sheet piling; second, to report on equipment required for pile driving; third, to collect information on special methods of driving sheet piles in cofferdams where conditions do not permit the use of ordinary equipment; fourth, to collect information on actual experience on the bearing power of piles and on the practical results of the use of formulas; fifth, to report on the use of guard rails for wooden bridges and trestles; sixth, to report on fire protection of wooden bridges and trestles. Of the above subjects those numbered 1, 4, 5 and 6 were considered. It seemed to the Committee that the pressure against steel sheet piling in place was something that was yet to be determined, and I am glad to be able to say that Cornell University is about to undertake a series of experiments to determine just what that pressure is. The experiments which they will undertake are not precisely those given on pp. 78 and 79, of Bulletin 141, but along different lines. This the Committee is not at all objecting to, because it gives the problem an additional point of attack; and the more points of attack we can give it the better. As for collecting information on the other three subjects, I beg to say a very large amount of data has been brought together. This has been formulated and tabulated and put in shape for the use of the Committee during the coming year, but the present Committee does not wish to make any recommendation to this meeting for its adoption. I make a motion, then, to receive our report as a progress report and information.

The President:—Would anyone like to say anything on either of these subjects mentioned by the chairman?

Mr. G. A. Mountain (Canadian Railway Commission):—Does this include the whole of the report?

The President:—Yes; you can make remarks on any subject.

Mr. Mountain:—Under subject 5, I would like to ask for information, whether that is a necessity where oil-burning engines are used.

Mr. Wentworth:—Mr. Mountain, as we have simply adopted this as a progress report, I think we had better not take the matter up in detail.

The President:—It would be perfectly proper to answer according to your individual opinion if you liked.

(The motion was then carried.)

The President:—The Committee is dismissed with the thanks of the Association.

DISCUSSION ON YARDS AND TERMINALS.

(For Report, see pp. 89-92.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON YARDS AND TERMINALS.

C. E. Lindsay. C. H. Spencer.

The President:—The next report is that of the Committee on Yards and Terminals, of which Mr. C. H. Spencer is Chairman. The Chairman of the Committee will make the preliminary announcement.

Mr. C. H. Spencer (Washington Terminal Company):—The Committee on Yards and Terminals have done a great deal of work this year in the collection of data on three of the subjects assigned to the Committee: (1) report on typical situation plans for passenger stations, etc.; (2) report on developments in the handling of freight by mechanical means; (3) report on developments in the design and operation of hump yards.

The information received was of such a nature that it was thought best to hold this over for a future report, a portion of which is to be written in the coming year.

The work presented to the Association this year is in the way of a report on subject (4), report on typical situation plans for a division engine terminal, which will be found on page 91. The Committee is a large one, representing about seventeen or eighteen different roads, and naturally a great deal of discussion occurred on this subject and the report presented is the boiled-down opinion of the Committee after the examination of a large number of plans of engine terminals that were presented for the consideration of the Committee.

The Secretary:—"(1) The engine terminal should be so located as to afford easy access to both Main Line and Yards, with the fewest possible reverse or conflicting movements."

Mr. Spencer:—I move the adoption of conclusion No. 1.

(The motion was carried.)

The Secretary:—"(2) The facilities provided should be arranged to permit of the most direct and rapid handling of an engine in its terminal in the order of its needs."

Mr. Spencer:—I move the adoption of conclusion No. 2.

Mr. C. E. Lindsay (New York Central & Hudson River):—I agree with the conclusion except it does not state in what order of needs the facility should be provided.

The President:—It is very general.

Mr. Lindsay:—The Committee provides that coal shall be taken when going out. From a motive-power standpoint that is desirable,

but from an operating standpoint and considering the question of time after the engine is ordered, it is desirable to coal an engine coming in, so that there will not be any necessity for its delay after it is ordered in going to its point of departure. The plan does not provide any facility for coaling an engine coming in, and if the plan was modified so that it might be possible to coal the engine coming in or going out, in the same manner that they take water coming in or going out, the conclusion would be much more desirable.

The President:—This is simply offered as information, and the conclusions need not affect the plan at all.

Mr. Spencer:—I call attention to the fact that provision is made in the plan for coaling on the inbound track; one track is placed next to the coal wharf for that purpose.

Mr. Lindsay:—Side coaling arrangement?

Mr. Spencer:—Yes.

(The motion to adopt conclusion 2 was put to vote and carried.)

The President:—The Committee is dismissed with the thanks of the Association.

DISCUSSION ON BALLAST.

(For Report, see pp. 95-300.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON BALLAST.

H. E. Hale. C. E. Lindsay. C. A. Morse.
Walter Loring Webb. S. N. Williams.

The President:—We will next consider the report on Ballast. Mr. H. E. Hale is Chairman; Mr. Hale will please make the opening statement.

Mr. H. E. Hale (Missouri Pacific):—The Ballast Committee would like to have the Association approve the definition of "Depth of Ballast" first, and then the conclusions of the three sub-committees.

The definition is as follows:

"Depth of Ballast.—The distance from the bottom of the tie to the top of the subgrade." (For definition of "subgrade," see Manual, 1911, page 16.)

Prof. Walter Loring Webb (Consulting Engineer):—As a matter of information, I would like to ask that the definition of sub-grade in the Manual be read.

The Secretary:—"Subgrade: The tops of embankments and bottom of cuttings ready to receive the ballast."

Mr. Hale:—The conclusion on page 97, proper depth of ballast to produce uniform pressure on the subgrade, etc., I move be adopted.

(The motion was carried.)

Mr. C. A. Morse (Santa Fe):—Regarding this report, which is based on the Pennsylvania experiment, on the value of cinders to help make up the 24-inch depth of ballast, we had an experience ten or fifteen years ago on a piece of line about twenty miles in length, with a foot and a half or two feet of cinders for ballast. We covered this with ten inches of slag ballast, and for at least four years we were having to work on that slag ballast continuously on account of the settlement of the cinders under it. While it showed up well as an experiment, it did not show up well in practice with us.

Mr. C. E. Lindsay (New York Central & Hudson River):—I am sure the Committee, in using the words "cinder ballast," does not preclude gravel ballast or better ballast?

The President:—No; the Committee would be glad to add gravel, if that would tend to make it more acceptable to the Association. If there is no further discussion, the question will be put.

(The motion was carried.)

Mr. Hale:—Under the heading of "Physical Tests of Stone for Ballast," your Committee recommends:

"For the description of the physical tests of stone for ballast as recommended by the Association and full instructions as to how the samples should be obtained and shipped to the Government, see Proceedings of the American Railway Engineering and Maintenance of Way Association, Vol. 11, Part 2, pp. 910-914, and report of Ballast

Committee of 1912. If blueprints of the machines used in making the tests are desired, they can be obtained from the Department of Agriculture, United States Government, Washington, D. C."

Mr. Chas. S. Churchill (Norfolk & Western):—While I think that this test may be all right, it is one that the railroads cannot ordinarily make, because they do not have ready at hand a diamond drill of this size, and do not have the means of cutting this core required in the test. We have been conducting, for several years, a test by means of cubes cut with a chisel and the relative strength of every stone can be determined in that way, just as well as it can by means of the cores. Therefore, while I do not wish to suggest that this test be not agreed to, I think there should be some latitude given for another form of compression test, such as can be readily made by any railroad without going to the Government.

Mr. Hale:—The physical tests of stone which are recommended in the Manual are covered by a description in the Proceedings of the Association and are made by the Government at Washington. They were originally started for testing material for wagon roads, and they were the most complete set of physical tests for stone that your Committee could find, and the fact that the Government makes them at Washington for any railroad or corporation or individual free of charge by sending the sample to the Government, made it, in the opinion of the Committee, very advantageous to accept these tests as described by the Government for use by the Association. It makes a very uniform test and is readily comparable with other stone known to the railroads. A sample of stone desired by Government for test is easily obtained by following the proposed instructions in the Manual.

I move that that be incorporated in the Manual.

(The motion was carried.)

The President:—There are no further conclusions by this Committee, the one on page 102 simply being a recommendation in regard to the continuance of the work. Would any member like to ask any questions of the Committee? If not, the Committee will be dismissed, with the thanks of the Association.

Prof. S. N. Williams (Cornell College):—I would like, as a member of the Committee on Ballast, to express the high appreciation which the Committee has for the experiments made by the Pennsylvania Railroad Company in reference to the necessary depth of stone ballast, and if it is not too late I would like to have a resolution passed, expressing our appreciation, as I know this matter has been of great service to us, and is one of those things we cannot properly reward in any other way. I personally feel very grateful to Mr. Cushing and the company and also to the United States Department of Agriculture for the help they have given us in our Committee work. I make this as a motion.

(The motion was carried.)

DISCUSSION ON TIES.

(For Report, see pp. 301-370.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON TIES.

W. M. Camp.	George W. Kittredge.	C. A. Morse.
W. C. Cushing.	C. E. Lindsay.	W. L. Seddon.
L. A. Downs.	Hunter McDonald.	Edwin F. Wendt.
John C. Sesser.	L. C. Fritch.	

The President:—The next report is that of the Committee on Ties, of which Mr. L. A. Downs is Chairman. Mr. Downs will make the opening statement for the Committee.

Mr. L. A. Downs (Illinois Central):—Mr. Chairman, the Committee on Ties was assigned six different subjects to make a study of and report, and we have reported on three. First, "the size of cross-ties required for the stresses to which they are subjected," and the conclusions to that are found on page 331. The second was, "tie renewals in continuous stretches vs. single tie renewals." The conclusion to that is found on page 342, and the third one we reported on is "the use of metal, composite and concrete ties;" the conclusion of that is found on page 370. I would suggest that we take them up in order.

First, "The size of cross-ties required for the stresses to which they are subjected." We sent out circulars and were very much gratified at the number of replies that we received, and you will find in Exhibit F, which commences on page 312 and ends on 329, some valuable information from members of the Association who replied to our questions and gave their experiences on different phases of the subject. On page 331 you will find our conclusions, which I will read:

"So far as your Committee is able to determine it is not feasible to lay down any fixed rule for the size and spacing of ties based on the A, B and C classification of density of traffic, for the following reasons, each of which in itself has a certain definite restriction, as well as an interrelation with all others, viz.:

"(1) Character of subgrade varies radically on the same road and in different parts of the country.

"(2) Kind of ballast varies widely.

"(3) Necessary depth of ballast varies with weight of axle loads, as well as density of traffic.

"(4) Necessary distance between face of ties varies with weight of axle load, as well as density of traffic.

"(5) Kinds of timber used for ties vary in different sections of the country.

"(6) Width of base rail (or weight of rail) and use of tie-plates,

"(7) Treated or untreated ties, crushing stress and durability.

"(8) Amount of labor spent on track maintenance.

"(9) Drainage.

"However, in general it may be considered good practice for Class A and perhaps B roads to space ties 10-in. to 12-in. face to face; the width of tie is not so important if 10-in. to 12-in. spacing face to face is followed; provided, however, the minimum width of face of tie is limited to 7 in."

I move the adoption of the conclusions.

The President:—The conclusions just read have been moved for adoption.

Mr. L. C. Fritch (Chicago Great Western):—It occurs to me that the Committee has left out a very important consideration in regard to the stresses to which ties are subjected. I think they should give us some information on what stresses ties are really being subjected to with our heavy wheel loads, and before we adopt these conclusions we ought to have some information on that line, and for that purpose I think it would be better to refer the subject back to the Committee for next year's work. The conclusions given are not definite and they do not give us much information, except in the instance of the last paragraph, and I doubt very much whether all the members of the Association will agree with the Committee on the last clause of their conclusion. There are many members who think that the width of the tie is an important question, even if the spacing is 10 to 12 inches, and it occurs to me that the conclusions as they now stand are hardly suitable for adoption.

Mr. L. A. Downs:—The first nine paragraphs enumerated are restrictions, rather than conclusions. The last paragraph is a conclusion that the Committee saw fit to make after taking into consideration the nine reasons why a fixed rule cannot be set for A, B and C traffic. It is a very hard matter to determine the stresses in ties, and we enumerated nine objections, after carefully considering the proposition as to why a fixed rule cannot be adopted for the railways to follow, and then we came to the conclusion in the last paragraph which we have up for adoption.

Mr. L. C. Fritch:—What I have in mind is this—in designing a bridge we assume a certain load. In designing a track we assume practically no load, and I think the time has come when we should pay more attention to the designing of track structure, just as we do to the designing of the bridge structure. We should assume certain heavy wheel loads and ballast conditions and design the track structures to conform to these, just as we do in the case of the bridge structure. I assume that this is an important subject for the railways. I am of the opinion that many of us think that the ties are too small, and are being subjected to too heavy stresses, and we should have more information on that line.

Mr. L. A. Downs:—In designing a bridge you have something to start out with; you have an absolute foundation, which is solid. You build the abutments and design the bridge for certain wheel loads. You have absolutely known factors to work on. In designing a track structure you must figure on subgrade, which is an uncertain quantity. As we enumerated in these nine paragraphs, we cannot lay down any fixed rule on account of the nine reasons given—the kind of ballast varies, the depth of ballast varies, the kind of timber used for ties varies, and there are various other reasons, and it is a very different subject altogether from a bridge proposition, where you have to start with some known quantity to work from.

Mr. L. C. Fritch:—I do not quite agree with the Chairman of the Committee. We can assume conditions which we can hope to reach. While the bridge structure is a different proposition, yet the principle is the same. We can assume certain conditions of ballast, foundation and load, and design the structure accordingly.

Mr. W. M. Camp (Railway and Engineering Review):—I take issue with Mr. Fritch. If he wishes the Committee to arrive at the design of the tie by mathematical investigation, I think his proposition is impracticable. Theoretical men have been trying to do that for the past thirty or forty years, and they have made all kinds of assumptions, but I have never seen a result that seemed to be worked out on practical considerations. In designing a bridge one has a truss or plate girder which rests upon supports at two points and the remainder of the structure hangs clear. In the tie we have nothing hanging free, and the strength of the tie depends to a large extent on the stability of the ballast or the earth supporting it.

Now, in reference to the conclusion as expressed in the last paragraph, I agree with the Committee if they intend what is my understanding of it, and that is, that the width of the tie, so long as it is up to standard size, is relatively not important. Of course, if it could be construed to include a culled tie, I would not support the conclusion; but if the necessary words were inserted to make it understood that the tie referred to is a tie of standard width of face, or larger, then I would agree with the Committee.

Many times we find the tie spacing referred to as a certain distance from center to center. If the ties vary in the width of face, that method of spacing is not a proper one. It results in a more uniform bearing surface to space the ties from face to face, rather than from center to center.

The President:—The Committee says it will admit that.

Mr. J. L. Campbell (El Paso & Southwestern):—Many of the railways are still carrying their track across steel bridges and wooden bridges on wooden ties, and it seems to me if we should assume the conditions which undoubtedly exist, or nearly exist on the bridges, we might arrive at some conclusions along the lines which Mr. Fritch

suggested. I believe it would be a good thing to determine just what the unit stresses are in a case of that kind.

Mr. C. A. Morse (Santa Fe) :—In discussing this tie question, and in figuring on adopting a resolution for the Manual, it seems to me we should not put anything in the Manual except what would be of particular benefit. We all know that we are up against the varying conditions set forth by the Committee to start with, and their report reminds me a good deal of the Underwriters' Code, which gives you a lot of negatives, but does not tell you what you can do.

We are up against this proposition, but there are a lot of different practices in vogue on the various roads, and it seems to me the Committee should take these conditions as they exist and investigate as to what is the best practice on all the roads, or on the various roads, and give a recommendation based on the best practice. As I understand the conclusion offered by the Committee, it practically gives no recommendation at all. I do not know how the rest of the members use the Manual, but every once in awhile, when I get up against something that causes me trouble, I hunt up the Manual to see what other people are doing. If I simply found the conclusion in the Manual as given by the Committee, it would be of no value.

Mr. C. E. Lindsay (New York Central & Hudson River) :—I speak in support of the position taken by Mr. Fritch. Assuming a stable condition of subgrade and a desirable condition of ballast, the maximum spacing of the ties would be determined by the height of rail and the weight of it. The minimum condition would be established largely by the method of track work and kind of tool used for tamping. Between these two conditions there would be a wide range of possibilities. I believe it is possible to assume conditions and determine with reasonable accuracy what is the best type of construction.

Mr. John C. Sesser (Great Northern) :—I wish to say that we have ties that have a face dimension of over 18 inches. I believe that the size of the tie should be limited.

Mr. Edwin F. Wendt (Pittsburgh & Lake Erie) :—This proposition may be stated in another way. There is a very practical matter which comes before engineers. In one section of the country it may be said that a standard tie is 6 inches by 8 inches by 8 feet long. In another section of the country it may be said that the standard tie is 7 inches by 8 inches by 8 feet 6 inches. The managements of railways are demanding from time to time the reasons why it is necessary to purchase the higher standard of ties; that is, a tie 7 inches thick instead of 6 inches thick and one that is 8 feet 6 inches long, instead of 8 feet.

It would be very helpful to the engineers if this Committee would approach this subject from the reverse standpoint from that which has been followed and first determine the stresses to which various ties are subjected and then draw a conclusion as to what size of tie is the

most economical under the loads which prevail in the railway practice of to-day.

Mr. L. A. Downs:—In Exhibit F you will notice in regard to question No. 11 the variety of answers received to that question from the different members of the Association who have given this subject study. Exhibit D shows the various kinds of ties used by the different railways and the number of miles on which a certain size of tie is used, and the number of miles on which another size of tie is used. Without having something definite to work on from the bottom, as we have in bridge work, it is very hard to determine stresses in ties.

Of course, it is an easy matter to refer the report back to the Committee for further consideration, investigation and report, but we must have some foundation to work on, and I think the conclusion as presented shows that we have considered something that is good practice.

The President:—I desire to make a statement on behalf of the Board of Direction. In assigning this subject to this Committee the Board had in mind that the report would be made on two lines, one line which the Committee has reported on to-day and the other line in harmony with what Mr. Fritch and Mr. Wendt have just stated. We knew, of course, when the subject was assigned that it required a number of assumptions to come to any conclusion regarding a subject of this kind, but because this subject is hard we did not consider that we ought to balk at it. A great many European engineers have already made studies on this line, and the Board thought it was about time that the engineers in this country took it up and tried to furnish some additional light.

It certainly is a very interesting study, and it will not do any harm to have such a study made. In going over this matter yesterday the Board mistrusted that a misinterpretation of the subject had been made by the Committee, and they, therefore, proposed a rewording of the instructions in line with what Mr. Fritch has already stated, namely, that they would like to have a study of possible stresses in the ties, and from that work to a rational design or size for a tie.

The Committee admits that they have been unable as yet to draw any conclusion from the collection of facts sent by the railways. It is, therefore, a very interesting subject for the Committee to pursue, and the Board would very much like to have the Committee do that, if the Association, after this explanation, feels that it is a good thing to do.

(The President put to vote the motion for the adoption of the conclusions on page 331, but the motion was not agreed to.)

Mr. L. C. Fritch:—I move this portion of the Committee's report be referred back to it for further consideration; that it be received as information as at present submitted, and that the Committee give additional study to the subject along the lines of the remarks on the subject.

(The motion was carried.)

Mr. L. A. Downs:—The second subject referred to the Committee was "Tie renewals in continuous stretches vs. single tie renewals." We sent out fifty letters to the different railways, asking certain questions in connection with this subject, and we were much gratified to receive thirty-five replies. The Committee considered these replies and came to the conclusion which appears on the bottom of page 342: "The Committee recommends the practice of single tie renewals." I move that the conclusion be adopted.

Mr. Hunter McDonald (Nashville, Chattanooga & St Louis):—I rise with a good deal of timidity to take issue with the Committee. I did not receive the Committee's circular. If I had done so, what I have to say now would have been printed in their report. I do not think it is sufficient reason to adopt this method of tie renewal as the policy of the Association simply because it is the common practice in this country. The replies received by the Committee to its circular and the statements of the Committee do not show that there have been any very great or deep investigations as to cost and other factors. They simply express the opinion that it is the best policy, without giving any facts to back up that opinion. I think this habit, you might say, of single tie renewals has grown up because of conditions for which none of us are responsible—because the managements of the railways are unwilling to incur the initial expense necessary to introduce another policy; in other words, if it should be shown to be desirable to have 12 inches of ballast under your track, and your ties all put in at one time, on given stretches of track, so that it would require very little work to be done for five or six years, it would entail necessarily a large initial expense, which would continue until the entire division had been so overhauled. After that time, I am firmly convinced that the cost of maintaining the track would be very much less than it is under the present policy.

Another reason why this habit has grown up is because of the waste of the remaining life in cross-tie that would come out under this renewal plan. There would undoubtedly be ties in the track that would last at least two years, and the Roadmaster would come along and criticise the section foreman for taking it out. On the other hand, if that tie was left in the track, in order to secure the additional length of life, which would probably represent 30 cents in value left in the tie, I believe it would require at least one dollar in labor to keep the track in condition while the value of the tie was being extracted. The labor thus expended is a concealed loss.

I realize that this problem is one that depends on a good many variable conditions; among them are the life and price of ties, cost and efficiency of labor, density of traffic, depth and condition of ballast, condition of the underlying roadway and the standard of excellence to which the track has to be maintained. I have endeavored to ascertain

what the labor costs are for maintaining the track in accordance with the plan recommended by the Committee. I have sought from our own accounts and from the accounts of other roads to find it out. I have found an utter lack of uniformity in the method of keeping roadway labor accounts, and it is simply impossible to make any comparison between the present method and any other method. I think we need a much closer analysis of our labor costs than we are now securing under the Interstate Commerce Commission distribution of costs. I think it would be well for our Committee on Records and Accounts to endeavor to formulate some standard subdivision of roadway and labor costs in order that we may arrive at some definite knowledge by which we may compare these things.

For the past eight or ten years one of our Roadmasters has been very diligent in observing the small amount of labor required to maintain stretches of track on which all the ties had been renewed at one time and he was so much impressed with the reduction in the labor cost of subsequent maintenance of these stretches that he received permission to try one experimental mile. That was put in in 1908, and we were paying 40 cents for first-class white oak ties. The track was laid with 80-lbs. rails; more than half the mile consists of 2-degree curves running in opposite directions, with 450 feet of tangent between them. The grades are slightly undulating. The freight traffic amounts to 2,000,000 tons per annum, and there are ten regular passenger trains per day, running at a maximum speed of 75 miles. The heaviest freight engines weigh 346,000 lbs., with a maximum axle load of 48,300. The heaviest passenger engine weighs 314,000 lbs., with a maximum axle load of 51,300 lbs. There was 9 inches of clean ballast under the track and a 3-inch additional lift was given. The cost was as follows:

3,000 ties at 40 cents	$1,200.00
1,263 cubic yards of ballast at 50 cents	631.50
Labor putting in ties and ballast and dressing up	844.00
Total, per mile	$2,675.50

A close account has been kept of the cost of maintaining this mile of track. The section foreman has been given special instructions to report each month the amount of labor expended in maintaining this track in line and surface. For the first year the cost was $23; second year, $29.80; third year, $35.20. We have just gone through the winter of the fourth year, and estimate the total expense will be $50; the fifth year we estimate at $75; and the sixth year, $110; in other words, we do not expect to renew any of the cross-ties in that mile of track inside of six years. This view, I think, is concurred in by a committee of engineers from an eastern road who visited our line. The cross-ties are all of first-class white oak. The average of the above figures for the cost of maintenance of the track per annum for six years would be $53.83.

Assuming that this track would run six years without any serious overhauling, one-sixth of the initial expense to put it in would be $445.83, and with the estimated annual expense for maintenance $53.83 would give an average cost per annum per mile of $499.66.

We do not know how this compares with results on other roads or even on our own line. We hope, however, to be able to tell you something about it in the near future. Since this mile was put up the results have been so encouraging that we are now carrying out the same policies on 45 miles of stone-ballasted track on that division.

From the best information I can get I believe the cost per annum of carrying out the policy recommended by the Committee, putting the price on the same basis as I have stated with reference to this experiment, would be about as follows:

Ties	$154.44
Labor putting in	77.22
One and one-half inches of ballast every two years	118.50
Labor surfacing and applying ballast	250.00
Labor of maintaining	100.00
Total	$700.16

This, as you see, would make a difference of about $200 a mile. Naturally, we assume that the ballast is clean to start with. I have taken no account of the fact that at the end of the first six years the necessary raising of the ballast, after it is overhauled again, would not require as much as three inches, and the annual cost would, therefore, be somewhat reduced.

We lack some standard method of comparing the excellence of our track. We can send a dynagraph car over the track, and get some idea as to what the line and surface condition is, but if we could devise some simple method of comparing the condition of the tracks with some standard, it would greatly simplify the matter of comparing cost of maintenance.

Mr. C. A. Morse:—In line with what Mr. McDonald said, I will say that on the Santa Fe we have a stretch of 55 miles of what we call an experimental track. Upon 22.5 miles we dug the track out and laid the ties to face, as Mr. McDonald suggested. We put in 12 inches of rock ballast, used creosoted ties, 3,200 to the mile, 90-lb. rail, and we have divided up our sections, so as to have them divide at either end of this 22.5-mile stretch, with an idea of keeping an account of the cost of renewals and repairs to see how it will compare with the renewal of ties individually. It has rather struck everyone that has looked at it that it may turn out that that will be the proper way to carry on renewals. We expect to get at least ten years out of these creosoted pine ties. On the basis that our rail has to be renewed at the end of ten years, it has seemed to us that the proper way to carry

on the renewal of ties would be to renew the ties to face at the time you renewed your rail.

Mr. W. M. Camp:—I will suggest that there is abundant opportunity at hand with almost any railway engineer to determine the relative economy of the method of renewing ties in continuous stretches, without going into specially conducted experiments. This opportunity may be found on any piece of new track. On such track, after the roadbed and ballast have become consolidated, there is an interval of several years during which no tie renewals have to be made; so that the expense of maintaining the track surface, with the disturbing element of tie renewals eliminated, can be ascertained. This average yearly expense should be taken in connection with the proportional yearly cost of renewing all of the ties at one time, as soon as the conditions may warrant; and in addition the expense of getting the track into normal surface condition and the ballast into the normal state of compactness, after the general overhauling; and in addition, still, the waste of timber in ties thrown out that would do for further service. The average annual expense of these various items, collectively, can then be compared with the usual expense of maintaining track in timber and in surface where the ties are renewed in patches, and solely with regard to their condition, individually, as to decay.

Mr. W. L. Seddon (Seaboard Air Line):—I think the results mentioned by Mr. McDonald and Mr. Morse are predicated on a much more uniform basis than the average railways get, and it seems to me that their conclusions are not based on the average results secured by the average railway. I think it is the uniform experience that when a new track is laid, that it is a very much more expensive proposition to keep this track in condition by renewing all the ties at one time than it would be to replace the ties one at a time. In the South, where we use pine ties and cypress ties, we begin to take out some of the ties from the track four years after the track is laid, while some of the ties remain in service fifteen years. I do not think it is fair to criticise the Committee's results by comparing what they propose with track laid with selected ties or treated ties. I think the Committee's conclusions are correct.

(The President put the motion on the adoption of the conclusion, which was approved.)

Mr. L. A. Downs:—The third and last subject assigned to the Committee was "the use of metal composite and concrete ties," and the conclusions are given on page 370. I move that the conclusion No. 1 be adopted.

(The motion was carried.)

Mr. L. A. Downs:—I will state in regard to the second conclusion that the Committee has not gone far enough in its investigations to be able to report anything definite, but the Committee has found that it promises to develop.

Mr. George W. Kittredge (New York Central & Hudson River) :—I move that the conclusion be accepted as information.

(The motion was carried.)

Mr. L. A. Downs:—I move that conclusion No. 3 be accepted as information.

(The motion was carried.)

The President:—The Committee has furnished us with some very excellent information, giving the experience of the railways with reference to different kinds of ties. It is extremely valuable. The Committee is dismissed with the thanks of the Association.

WRITTEN DISCUSSION ON REPORT OF COMMITTEE ON TIES.

Mr. W. C. Cushing (by letter) :—The report of the Committee on Ties is always looked forward to by the members of the Association on account of its interesting statement relative to the progress and development in the use of concrete and metal ties, as well as for the treatment of the other subjects embodied in it, and the report this year is no exception to the rule. Our information with reference to the concrete and steel ties under examination from time to time has been brought down to date.

The relative life of wooden and iron or steel cross-ties is a subject of much speculation, because no metal ties have been in use in this country for a sufficiently long period to enable their life to be accurately determined, and consequently we keep looking to Europe, and especially to Germany and Switzerland, where the metal tie is most widely used in Europe, for information of that nature.

The writer, therefore, submits the latest note on the subject, taken from the Bulletin of the International Railway Congress, No. 2, February, 1912:

"THE LIFE OF WOODEN AND IRON TRANSVERSE SLEEPERS.

By Mr. Cauer.

(Zeitung des Vereins deutscher Eisenbahnverwaltungen.)

"One of the most important advances made in technical matters is the recognition that in determining the value of any technical system, one of the most important considerations is its economy. Naturally we strive for perfection in our designs. But even the most ingenious design is to be condemned, if it does not prove economically satisfactory; there is no justification for taking the technical point of view alone and declaring a design satisfactory, if it is not so from the economic point of view as well. Hence, it is very satisfactory if a question of very great economic importance, such as the life of superstructure materials and especially of transverse sleepers, is brought nearer to solution, as has been done by the work of Mr. Biedermann, permanent way and traffic inspector in Germany. Short particulars of his first paper in the Organ für die Fortschritte des Eisenbahnwesens and of a more detailed lecture to the Verein für Eisenbahnkunde have already been published in the Zeitung des Vereins deutscher Eisenbahnverwaltungen. Considering the great importance of this question, we give a more detailed account of Mr. Biedermann's investigations and their results, as described in the lecture in question.

"Mr. Biedermann takes as his basis that the superior superstructure is that which for an equal outlay gives the greatest advantages, or that for which a greater outlay is justified economically by important technical advantages. In this connection he considers more especially the question of what are the most advantageous sleepers; as regards this point, technical opinion varies widely. While England, France, Belgium, Holland and Austria, in short nearly all other European countries except Switzerland, and also the United States of America, use wooden sleepers nearly exclusively, the German railways have very extensively adopted iron sleepers. But the different railway administrations in Germany are also not unanimous on the subject. At the end of 1909 about 31 per cent. of the total track of the German railways was laid on iron transverse sleepers. An important factor as regards this ratio is the system of the Prussian-Hessian State Railway; 30.4 per cent. of its track was on iron sleepers. The practice of the other State railway administrations in this respect is noteworthy. While Saxony, Oldenburg and Mecklenburg have no iron sleepers, except on experimental sections, Baden, on the other hand, has iron sleepers nearly exclusively. Bavaria, with a total of 12,000 kilometers (7,450 miles), has about 3,900 kilometres (2,420 miles) laid on iron sleepers, and Wurtemberg, with a total 3,500 kilometres (2,175 miles), has nearly 1,800 kilometres (1,120 miles) on iron sleepers, that is, more than half. On the other hand, Alsace-Lorraine, with 4,400 kilometers (2,735 miles), has only about 350 kilometers (218 miles) on iron sleepers, or 8 per cent. It is specially noteworthy that Saxony, a busy industrial state with much traffic, follows the examples of England and Belgium. These countries, although their iron works and rolling mills are highly developed, still use wooden sleepers, which they cannot obtain from their own forests, while Baden, poor in iron works, but rich in forests, has since 1890 been adopting iron sleepers at a quicker rate than even Prussia.

"The cost of procuring iron sleepers, even if we allow for the higher value of the wornout sleepers, is materially higher than that of wooden sleepers. Thus, for instance, according to Mr. Biedermann, the price of a standard iron sleeper on the Prussian-Hessian State Railway was 6.55 marks ($1.64) in 1911, while that of a standard pine sleeper, pickled with creosote, was 4.20 marks ($1.05). The iron sleeper must accordingly present great advantages, if this much higher expenditure is to be justified.

"Mr. Biedermann is now of opinion that in this respect the comparative life of two different sleepers is a criterium of their technical value. The life, he states, registers 'automatically and conscientiously the technical advantages and disadvantages together with the quality coefficients which are to be used in a technical and also economical comparison. They represent a summary of the incommensurable alleged or real technical advantages and disadvantages.'

"These assertions go somewhat too far. Thus the more or less easy or difficult maintenance of the gage and alinement of the track is of considerable importance in determining the technical value of a system of sleepers not only because this maintenance costs more or less, but also because a track which is easy to maintain is on the average in better condition for the traffic. Moreover, there are other considerations, such as the nature of the ballast, which depends on the kind of sleepers used, the greater or lesser stability of the track when a train passes, the suitability for switches, the greater or lesser difficulty of using the sleepers again when alterations are made, etc.; all of these are of importance when considering the merits of the system, and they find no expression in a mere statement as to the life. But subject to these limitations, we are able to agree with Mr. Biedermann to this extent, that the life of the sleeper is the

most important factor in determining whether the higher price of a system of sleepers is justifiable, but it will also be necessary to consider the cost of ballasting and of maintenance.

"Mr. Biedermann next sets forth that it is not a question of the life of a few specially favorable cases, but of the mean life of a given system, and that we have hitherto had no information about this point. While the limits of the mean life of wooden sleepers have been gradually determined by observations made during the last seventy years in countries in which there are railways, we have to depend, as regards the length of life of iron sleepers, on a few isolated observations, or even on estimates. Thus railway engineers have made estimates of the life of iron sleepers varying between fifteen and fifty years.

"As against this Mr. Biedermann emphasizes that reliable figures can only be obtained if a considerable length of track laid uniformly with sleepers of one kind is kept under observation during a longer period of years, and if the ratio is determined of the yearly replacement of sleepers (reckoned as length of track) to the total length of the railway network in question. For this purpose, Mr. Biedermann has devised a graphic method, which he then applies to the figures concerning the laying and the maintenance of sleepers, published in the statistics of the German Reichseisenbahnamt. In his calculations he uses, not the number of the sleepers, but the length of track equipped with the sleepers in question.

"This graphic method, which the lecturer explained in detail with the help of lantern slides, can only be briefly described here. As a basis the simplified assumption is made that the track in question laid on uniform sleepers has only been renewed once in course of maintenance. Laying the sleepers and maintenance are represented by two curves whose abscissæ represent the time since the sleepers in question were laid or maintenance began; while the ordinates represent the total sleepers used up to the time in question; in the case of the laying curve, the sleepers originally laid; in the case of the maintenance curve, the sleepers used for maintenance. The ordinate of the maintenance curve is always smaller than the ordinate of the laying curve for the same year, because the sleepers laid during late years have not arrived at the period of regular renewal. If we consider a period of time from the point of view of the sleepers renewed in it, then the last ordinate of the maintenance curve, which represents the sum of all the renewals made during the period in question, corresponds to an equal ordinate of the laying curve, a number of years ago, which represents the sum of the sleepers laid up to the period in question. In this the assumption is made that the renewal has extended exactly over the period the laying curve covers up to the ordinate in question. The mean center of the part of the laying curve extending thereto represents the mean time of laying all the sleepers; the mean center of the whole maintenance curve (up to the last ordinate) the mean time of the renewals. Accordingly the horizontal distance between these two mean centers represents the mean life of the sleepers which have been replaced. In the case of the older tracks, sleepers were replaced two or more times; in these cases the method is supplemented by another method, allowing for this repeated replacement, and there is also a furthr supplementary method. In addition, special attention has to be paid to the switch sleepers, and corrections or subsidiary calculations are necessary when wooden sleepers have been replaced by iron sleepers or vice versa, when the system of iron longitudinal sleepers was adopted and when it was abolished, finally, also, in order to allow for the constantly varying number of sleepers used per unit length of track.

"The lecturer then applied his method in order to determine the mean life of the wooden and iron transverse sleepers used on the Prussian-Hessian State Railway. He found that the mean life of wooden

sleepers differed but slightly from that of iron sleepers, in fact, it was slightly lower in the case of iron sleepers. In both cases it varied between about 15 and 20 years. Similar results were obtained when this method was applied to the iron sleepers of the Baden State Railway.

"Mr. Biedermann himself remarks that these results are to be interpreted with caution. The wooden sleepers renewed include oak and beechwood sleepers, formerly used in greater quantities; moreover the time covers the older years before the increasing traffic made the many important improvements since adopted necessary, such as the newer systems of pickling, the use of treenails, reducing the spaces between sleepers, using longer sleepers, fastening the rails more securely, etc. But according to Mr. Biedermann the figure determined by him for the life of wooden sleepers is especially lowered by the fact that he treats all the lines taken over by the Prussian State Railway as newly laid lines, whereas in reality the sleepers of these lines were already in part considerably worn. On the other hand the life determined for the iron sleepers, which in some cases is less than 15 years, is too low, for all the sleepers are included which were used in the early years of experiment; now it is only comparatively recently that the present heavy and good shapes are used while, as in the case of wooden sleepers, the number of sleepers per rail length is increased, and the quality of the ballast is also continually being improved. Taking everything into consideration, Mr. Biedermann draws the conclusion that the present creosoted pinewood sleeper, when hard broken stone is used as ballast, will have a life of 18 to 20 years, and that the life of iron sleepers will hardly exceed this. On the other hand, the new iron ribbed sleeper should have a life of 34 years, taking into consideration its higher price, and the more expensive fastenings and ballast required, if it is to be economically equal to a wooden sleeper having a life even of only 15 years. According to Mr. Biedermann, this decides the economic contest in favor of the creosoted pinewood sleeper.

"Mr. Biedermann's statements met with much approval; in opposition to them, one speaker specially emphasized that it was only comparatively recently that the original shape of the iron sleepers, which proved unsatisfactory, was altered and more suitable designs were introduced, so that the life determined by the lecturer was much too short, and that the question of the economy therefore still remained an open one. The following criticisms of Mr. Biedermann's researches may also be brought forward.

"In the first place, what he only incidentally remarks must be emphasized, that his graphic method only gives the mean life of the sleepers which have actually been taken out and renewed, not that of all the sleepers laid. Hence, particularly in the case of lines where the sleepers have not yet attained the longest age or even the average age of the kind in question, it gives too low figures for the mean life, for the sleepers which are renewed do not include just those which have the longest life. On old lines this error it is true becomes reduced to a minimum, but it always remains, so that it may be said that the Biedermann method always gives too low values for the life, which in the case of old lines approach the true values asymptotically. Now this fact must affect and have an unfavorable effect, as regards iron sleepers, on the results of Mr. Biedermann's investigations, for the newer designs of these sleepers have not yet been in use during the period of time which may be estimated to represent their average life, and accordingly there are probably still many of them having a long life which do not at all appear in the calculations. On the other hand, Mr. Biedermann does not take into consideration the cost of maintenance, which is greater, particularly the first few years, with iron sleepers than with wooden sleepers, and accordingly is unfavorable to iron sleepers in making an economic comparison. It must

also be taken into consideration that during alterations wooden sleepers frequently become useless which otherwise could still have remained in use for a much longer number of years, while iron sleepers do not show this disadvantage. It remains doubtful what influence the rebuilding of stations has from this point of view exercised on the life of the iron and wooden sleepers as determined.

"Finally, the statistics utilized by Mr. Biedermann give no information about the reasons why the wooden and iron sleepers were renewed. Wooden sleepers are, as a rule, finally taken out, also in the case of sidings, if they have become so damaged by the traffic and by the repeated fixing of the rails that the screws no longer hold. The question then arises in the case of iron sleepers, to what extent the reason for renewal was their becoming damaged in a similar way, to such an extent that they became useless, and to what extent other causes were operative, which could be removed or ameliorated by increasing the weight of the sleepers, or improving their shape or the fastenings.

"But even if we assume that the life of iron sleepers as compared with that of wooden sleepers should prove on careful investigation (which would involve sundry other points which it would take too long to discuss here) to be considerably more favorable than as determined by Mr. Biedermann, yet the difference as calculated by him is so great that in comparing the two kinds of sleepers, the scale seems to turn strongly in favor of wooden sleepers. Hence, it would be very desirable that the administrations using iron sleepers on the large scale should give particulars of their experience, which would probably elucidate the reasons why the sleepers were renewed and show what final conclusions can be drawn so as to settle the problem of the sleepers."

DISCUSSION ON TRACK.

(For Report, see pp. 371-386.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON TRACK.

F. J. Bachelder.	C. H. Ewing.	C. A. Morse.
J. B. Berry.	L. C. Fritch.	H. T. Porter.
Geo. H. Bremner.	J. B. Jenkins.	L. S. Rose.
W. M. Camp.	George W. Kittredge.	J. A. Spielmann.
J. L. Campbell.	C. E. Lindsay.	

The President:—The next report is that of the Committee on Track, of which Mr. J. B. Jenkins is Chairman. Mr. Jenkins will make the preliminary statement for the Committee.

(Mr. Jenkins read the preliminary statement of the report, and said:)

Mr. J. B. Jenkins (Baltimore & Ohio):—Your Committee has revised the plans for Nos. 8, 11 and 16 Rigid Frogs, No. 11 Spring Frog and for 11-ft., 16½-ft., 22-ft., and 33-ft. switches and submits them for adoption as general plans representing good practice.

Your Committee has also revised and combined the "General Specifications for Frogs, Crossings and Switches," adopted by the convention of 1910, and the "General Instructions for Ordering or Contracting for Frogs, Crossings and Switches," submitted to the convention of 1911 and received as information, and submits them for adoption as representing good practice.

At the convention of 1909, the Association instructed the Track Committee to recommend three standard lengths of switches and three standard numbers of frogs; such a recommendation was made, with the modification that a fourth length of switch was added for special cases requiring frogs of large angle; the recommendation was embodied in Conclusion (4) of your Committee's report, which was adopted by the convention of 1910, but was referred back to the Committee by the Board of Direction for reconsideration.

Your Committee reconsidered and reaffirmed its former action; the conclusion was not resubmitted, however, excepting as the proposed lengths of switches and numbers of frogs were embodied in the "General Instructions for Ordering or Contracting for Frogs, Crossings and Switches," which was received only as information by the Association at the convention of 1911.

In determining the lengths of switches your Committee considered it necessary to provide for the following general classes of turnouts:

(a) Turnouts to be operated over the divergent route at the maximum practicable limited speed.

(b) Main line turnouts and crossovers to be operated over the divergent route at low speed.

(c) Yard turnouts.

(d) Turnouts requiring frogs of large angle.

With regard to the second and third subjects assigned to the Committee, the Committee has been studying the question of track fastenings and has made good progress, but has nothing as yet to report.

In regard to the third subject, "Study Designs for Main Line Turnouts," we considered it necessary to hold that subject in abeyance pending the adoption of three standard numbers of frogs and three standard lengths of switches, provided it is the wish of the Association to adopt such standards. If the Association wishes to adopt a greater number of standards, the Committee will prepare designs in conformity with those standards, and then the range of our study will be much larger.

On the first subject we originally submitted the plans for frogs and switches as a part of the specifications, but there has been some objection on the part of some members of the Association on account of the plans being in too great detail, and on the part of others because they are not in sufficient detail. Part of the Association considered that the plans should not be a part of the specifications, another part, apparently, thought the specifications should be accompanied by complete and detailed plans. The Committee, at the last convention, submitted plans for these frogs and switches, which we have subsequently gone over carefully and revised; we also revised and combined the "General Specifications for Frogs, Crossings and Switches," which were adopted in 1910 with the "General Instructions for Ordering or Contracting for Frogs, Crossings and Switches," which were submitted in 1911, and received only as information; we now wish to submit them for adoption. We wish to submit the specifications and the plans separately.

At the request of the President, the Committee will ask action on conclusion No. 2, that the plans of No. 8, No. 11 and No. 16 rigid frogs, No. 11 spring frog and 11 ft., 16½ ft., 22 ft., and 33 ft. switches be adopted as general plans representing good practice. We ask action on this under Rule 16-g. The adoption of these plans has no bearing on conclusion No. 3, which recommends these frog numbers and lengths of switches. The adoption of conclusion No. 2 only carries with it the recommendation of these plans for these frog numbers and lengths of switches. The plans, it may be stated, are general plans, principally for dimensions. I move that conclusion No. 2 be adopted with recommendation to publish in the Manual.

(The motion was seconded and carried.)

The President:—It is open for discussion.

Mr. J. L. Campbell (El Paso Southwestern):—Referring to the plans for the 33-ft. switch on page 385, as a matter of information, I would like to ask if the Committee came to any conclusion in relation to the joints in the main line rails. As far as I see, this plan does not show the location of any of the joints; and also whether or not the Commit-

tee has considered special rail lengths for these turnouts. How does the Committee propose to handle turnouts in case the proper length does not make up commercial lengths of rails? Where would the Committee put the joints in the main line for this switch?

Mr. Jenkins:—The Committee has considered both questions raised. In regard to the joint for the 33-ft. switch, we consider that the best practice would be to use a 60-ft. stock rail.

The President:—Any additional remarks on this motion?

Mr. Jenkins:—The plans for the switches are general plans and are the ones the Committee had in mind in drawing up the specifications, although we wish to detach them from the specifications. The specifications say, "Heel blocks shall be of approved design, with standard rail drilling." The plan itself says: "Filler of approved design." We could not indicate more than one form of heel block on the plan, so we only indicated the one shown.

Mr. J. A. Spielmann (Baltimore & Ohio):—Mr. President, on page 381, first paragraph, five inches is recommended for throw of switch. I would like very much to know how the Committee arrived at this conclusion. I think five inches is more than necessary and that 4½ inches is quite sufficient.

Mr. Jenkins:—There is sometimes a little drag in the switch point in throwing the switch, especially with the longer switches; this interferes somewhat with the flangeway, and with some of the heavier sections with the broader head, 4½ inches does not seem to be quite sufficient and 5½ seems to be preferable. In other words, the switch rail does not always take the same curve when the switch is thrown and does not always leave the same distance between the stock rail and the back of the switch.

Mr. C. E. Lindsay (New York Central & Hudson River):—The drawings on pp. 382, 383, 384, 385, all have relation to the drawing Fig. 2, page 382, and you will note that the first pair of holes, 5 inches apart, are 1½ inches from the point. That, I believe, is done at the behest of some of our signal friends who desired to put on a modern type of front rod for the locking apparatus at interlocking, and that requires alternate spacing of ties. If it is safe to allow the switch point to project (as it will for the use of the head rod of that type in those holes) over a foot beyond the first rod, it would be better, it seems to me, to adopt the alternate spacing of ties shown here, rather than the primal one, because it would be safe to fasten a head rod at these first pair of holes and between the ties. I do not consider the alternate spacing of the ties shown on the plans as necessary in any way whatever, and it is objectionable because it necessitates a change in these ties when changing from a hand-thrown switch to an interlocked one. The plates on the first two ties are also unnecessarily long.

Mr. Jenkins:—We do not think that all roads would want the first spacing of ties shown, but some of them would prefer the alternate spacing, so we have shown both of them on the plans for that reason. If

any road desires to use the first spacing for interlocked switches and considers that the best practice, there is no reason why they should not follow that spacing throughout.

The President:—If there are no further remarks, the motion will be put on the adoption of this resolution to go in the Manual.

(A vive voce vote not being definite, a rising vote was then taken, as follows: In the affirmative, 23; opposed, 13, which caused hearty laughter.)

Mr. Jenkins:—The Committee asks consideration of the third conclusion. This recommendation was made with full knowledge of the consequences. We were asked by the Board of Direction, or rather by the Association itself, to recommend three frogs and three lengths of switches. We thought it necessary to include the fourth length of switch for industrial sidings and other short turnouts, where such turnouts are required. In recommending these three lengths of switches, with one additional length for special cases, we took the 33-ft. rail as a basis and took such fractional parts of that length as to cut the rail economically, making the lengths 33, 22, 16½ and 11 feet. Our principal reason for doing this is that we want the very best rail for the longest turnout, and we can probably get the best rail by using a 33-ft. length. We will probably also want to specify that this rail shall come from a certain part of the ingot. As to the frogs, we are perfectly aware, in recommending No. 11's, that there are very few of them in use at the present time and that more roads use No. 10 than any other number of frog; but if we adopt a No. 8 for yards and No. 10 for main line turnouts, that only leaves us one other turnout to use for both the low and the highest restricted speed, and while the No. 11, with the 22-ft. switch point, will answer for the low-speed turnout controlled by interlocking just about as well as the No. 12, while the No. 16 will answer fairly well for the highest restricted speed, because the deflection of an engine through the lead of No. 16 is about the same as that through the 33-ft. switch point. So the No. 11, if we are confined to three numbers, will answer the purpose of the present No. 10 and 12, while the No. 16 will answer the purpose of the 14, 15, 16, 18 and possibly the 20. As to the No. 8's: I think the present practice for yard turnouts is tending very strongly towards No. 8, so that our recommendation in that regard is not at variance with practice. Another reason for the No. 11 is that if we adopt a standard for general use, we want to take that number of frog which will give the most economical use of the rails, and if you will refer to the table of practical leads in the Manual, you will find that a No. 11 is best suited for that purpose.

Our Committee would like definite action on this, either adoption, or rejection with further instructions, because our study of main line turnouts depends on your action on this conclusion. If the Association thinks that three numbers of frogs are not sufficient, we will very gladly take up a recommendation for a greater number; but the Committee itself feels that these three frogs are sufficient. Of course, every railway which uses No.

10's would not want to tear out all the No. 10's and put in No. 11's; but there is no necessity for doing so. When new work is laid out it can be done with No. 11's and eventually the railways will come to these three standards, which will be economical standards. I move the adoption of conclusion 3, and that the recommendation be published in the Manual.

(The motion was seconded.)

The President:—The subject is now open for discussion.

Mr. L. C. Fritch (Chicago Great Western):—Mr. Chairman, the Chairman of the Committee has given me a suggestion in his remarks that might make that conclusion acceptable, that in all new work, the length and the switches, the numbers of frogs recommended by the Committee be adopted.

The President:—New work and renewals?

Mr. L. C. Fritch:—No, not as broad as renewals—in all new work.

Mr. Jenkins:—The recommendation of the Committee itself is that all new work should be laid out, so far as practicable, with these three frogs, so as to effect the gradual elimination of frogs of other numbers, lessen the cost of manufacture and decrease the amount of stock carried.

Mr. L. C. Fritch:—Then I move it be included in No. 3.

The President:—There is no objection to putting those words in the conclusion.

Mr. George W. Kittredge (New York Central & Hudson River):—I am not altogether satisfied with the reasons given why we should go from No. 10 to No. 11. I know a great many roads that use No. 10 quite generally, and it was only a few years ago that a No. 10 frog was considered one of the maximum numbers to be used in any location.

Mr. Jenkins:—It is in the lead that we use the rail to better advantage. We have a 33-ft. rail and practically no cutting, with the No. 11 frog and a 22-ft. switch point. Take the No. 10 frog; for the best results we ought to have a slightly shorter switch point, somewhere around 20 ft. Of course there is not very much difference practically, but a No. 11 frog with a 22-ft. switch point would give a little better turnout than a No. 10, and will give but little sharper turnout than a No. 12, which is now very generally used for low-speed turnouts which are controlled by interlocking.

Mr. C. A. Morse (Santa Fe):—I favor the motion, for the reason that I think if we are going to work plans out, as the Chairman says, and get results in regard to our frogs and switches, that we will have to come to some standard. On our road we have been through the agony of changing standards. We could not wait for the Association and we adopted 8, 10 and 14. I think 8, 11 and 16 are all right. In regard to Mr. Fritch's proposition to add to that a new frog, I do not believe any road that has adopted a set of standards is going to change them to go with this, but there are a good many roads, I presume, that are about up to the point where they will have to change their standards, the same as we were a few years ago when we were

using 6½ and 9. We finally adopted 8, 10 and 14. I favor the recommendation.

Mr. W. M. Camp (Railway and Engineering Review):—What degree of turnout curve results from the combination of a No. 11 frog and a 16½-ft. switch point?

Mr. L. C. Fritch:—I want to offer the suggestion that conclusion 3 be subdivided into two parts, one governing recommendation in regard to length of switches, and one in regard to number of frogs. It is possible that some can agree on the number of frogs, who would not agree on the switches, and vice versa.

The President:—There is no objection to that; so the motion will be revised to include frogs only. The Association will consider that the motion is revised so as to include frogs only at the present time.

Mr. J. L. Campbell:—In that connection I wish to suggest that it probably would be of interest to a great many members of the Association to hear from the engineers who have adopted and use a 33-ft. switch rail.

The President:—We will wait until we come to that part.

Mr. Kittredge:—We have already adopted the plans for Nos. 8, 11 and 16 frogs. It might be a little inconsistent if we voted any other way than to adopt the frogs.

The President:—We are not adopting the numbers in adopting the plan.

Mr. Jenkins:—The No. 11 frog, with 22-ft. switch point, takes four 33-ft. rails for the lead curve, one of which is cut to 32.85 or 1⅞ inches cut off of one of the four rails.

Mr. Lindsay:—Is Fig. 2 adopted by our adoption of conclusion No. 2?

Mr. Jenkins:—It was not so intended. Figs. 1 and 2 are a part of the specifications.

(The motion was carried.)

Mr. Jenkins:—I move that the Committee's recommendation in regard to lengths of switches be adopted, with recommendation to publish in the Manual.

(The motion was seconded and carried.)

Mr. L. C. Fritch:—I move to amend the recommendation by specifying the switches 11 ft., 16½ and 26 ft.

(The motion was seconded.)

Mr. Jenkins:—It is the opinion of the Committee that 26 ft. does not give quite a small enough angle for the highest restricted speed for junctions; that we should use as long a switch point as possible, and that in addition we want to use the full length of rail in order to have every possible assurance of getting the very best rail for that switch point. I would like to hear from Mr. Porter on that subject.

Mr. H. T. Porter (Bessemer & Lake Erie):—Several years ago, when the matter was brought before the Committee, they came to the conclusion that for high-speed crossovers and turnouts, it was desirable to have as long a switch point as practicable, under the conditions that we were

working with. After conferring with the railmakers of this country we found that 93 or 94 per cent. of the rail which they sent out was to a standard of 33-ft. lengths. Now I suppose it is not necessary at all to tell anyone who has had any experience with switches that if we could get a switch point 100 per cent. better than anything we ever saw, it would be a very desirable thing. Therefore, we felt that we should get the best possible rail, considering every little detail. If you accept the 33-ft. rail, then you can specify just the part of the ingot it comes from. The rails being rolled now are marked A, B, C, D, depending on whether the top rail of the ingot, the middle rail of the ingot, or the last rail of the ingot. So we can put it in the power of the engineers to specify where that rail shall come from, and they can do that with the 33-ft. length switch, or with switches made out of 33-ft. length rails. Five per cent. of the rails are, as a rule, of shorter lengths, dropping down according to the various specifications, either a foot at a time or two feet at a time. So, if you have a 26-ft. switch, the chances are you will get it out of a shorter rail. So much for the rail. Another object in having the *longest* rail we could get was to make the curve in the lead as light as possible. In France they are using now, at their junctions, a rail 39 feet and some inches long, and they are using them successfully and are maintaining a speed through the switches, even on the branch line, of 62 miles an hour without a shock. That seems to be the tendency in France, and I believe in some of the other European countries, they are making experiments in the same direction. So we feel that we ought to at least go as far as 33 ft. in order to get as light a curve as possible.

After adopting the switch point that gave us the lightest curve in the lead, it was figured out by one of the members of the Committee to put the frog on a par with that condition, a frog that would give a curve producing the same deflection as an engine passing through that point, and it was found to be a No. 16 frog. So, for the purpose of getting the best rail, the lightest curve, and to get a point that would give the same deflection as the curve of a No. 16 frog, we feel that we ought to use a 33-ft. point. Furthermore, we feel that we ought to try, in a measure, to keep pace with the other countries in trying to get leads whereby we can obtain speeds the same as they are doing in Europe.

Mr. J. B. Berry (Chicago, Rock Island & Pacific):—In looking at the bottom of page 386, I find five members of this Committee who do not agree with this report, and I would like to ask the Chairman why. It occurs to me that perhaps they have some such a reason as I would suggest. We have passed a resolution here that we accept the plans for the frogs as a whole. I think there are probably very few who would object to Nos. 8, 11 and 16 rigid frogs, but some of us might seriously question whether we wanted to adopt No. 11 spring frog. While the Association passed them altogether, it seems to me these five members had something in mind as I have suggested. It may be unwise to commit this Association to that type of a spring rail frog; others of us believe there is equally as good, if not a better, spring rail frog, and it would seem——

The President:—Mr. Berry, I do not think you are in order on the frog question now. This is strictly on the switch points. The resolution for the frogs has been passed.

Mr. Berry:—I thought the split switches were concluded. Here is this——

The President:—This is on switch points.

Mr. Berry:—What did those five members say about switch points, those who dissented from the majority of the Committee?

The President:—Any remarks from the Committee?

Mr. Berry:—When I am in order, I wish you would put me right, and I will start in again.

The President:—We will now adjourn and the remaining questions will be taken up in the morning, on the length of switches, and also the specifications.

(Adjourned until 9 o'clock a. m., Wednesday.)

The President:—The further consideration of the report of the Committee on Track will now be taken up. The consideration of the report was suspended last evening while we were discussing conclusion 3 on page 374, with reference to the lengths of switches and number of frogs, and this question is now open for discussion. Mr. Jenkins, the Chairman of the Committee, will continue the presentation of the report.

Mr. Jenkins:—The question was asked yesterday as to the particulars in which the dissenting members of the Committee disagreed with the majority; I did not have all the letters with me at that time, but I think I have all the information here at the present time.

Mr. George H. Bremner disagreed, not in regard to the conclusions, except that he wished the conclusions "presented" as representing good practice, instead of "adopted" as representing good practice. He also objected to some portions of the presentation of the facts in connection with the choosing of the numbers of frogs and lengths of switch points, evidently taking that part of the report as an argument. I did not have that intention. I wanted to give the facts for and against rather than to present an argument for the conclusions of the Committee.

Mr. Rote writes: "I am willing to agree that the report of the Committee represents good practice, but I am not willing to agree to a report favoring the switch with the raised switch rail for the solid-plated frog over flat switch and a frog on individual tie-plate. As you perhaps know, our company (Lake Shore) uses the flat switch and does not use a single solid plate under ordinary frogs, and, therefore, I do not approve of the findings of this Committee in this respect."

Mr. Ray writes: "I am willing, of course, to go on with the Committee, assuming that the majority are in favor of the report as submitted. I do not agree, however, with the Committee on the recommended length of switch for frogs over No. 14, that is, 33-ft. switch points. I do not believe that the 33-ft. switch point is in every way practical. Your plan does not indicate how the stock rail joint is to be made or where it is to be placed. Furthermore, I do not see the advantage of a No. 11

over a No. 10 frog for ordinary yard work. You are given permission to sign my name to the report with the understanding that I do not agree with the recommendations referred to above."

It may be stated that I do not think there is any disagreement between Mr. Ray and the rest of the Committee concerning the relative merits of the No. 10 and No. 11 frog for ordinary yard work. The Lackawanna uses No. 10 almost entirely for yards, while most roads use 7's and 8's, and some roads 6's, in similar places.

Mr. Bruner writes: "I subscribe to the Committee report, excepting the detail drawings of frogs and switches and frog numbers."

Mr. Stevens writes: "In relation to the report of the Track Committee, I have crossed and marked out such portions of the proposed text as in my opinion should be omitted and have signed a copy and returned it to you by mail."

The portions marked by Mr. Stevens are several slight changes in that part of the report which precedes the conclusions, and crossing out three paragraphs on page 372 following "(d) Turnouts requiring frogs of large angle." Mr. Stevens wished me to omit these three paragraphs as not being a proper portion of the argument. As stated before, I consider this as introductory rather than as an argument for the position of the Committee. Mr. Stevens wanted the conclusion in regard to switch points to read 22-ft. points for No. 10 frogs instead of 16½ points. He wanted conclusions No. 1 and 2 to read: "The Committee recommends General Specifications, etc., as representing good practice," and "The Committee recommends the General Plan, etc., as representing good practice."

His only objections are in regard to those two points mentioned. I would like to state that the question of 33-ft. switch points has had a great deal of discussion covering a period of about three years, in the Committee, and the Committee is very nearly unanimous in concluding that 33-ft. switch points are desirable. It is to be remembered that 30-ft. switch points came into use when the longest rail rolled was 30 ft., and it was not possible at that time to have a stock rail without a joint. Now with the 33-ft. switch point we can very readily obtain a 60-ft. stock rail, when it is desired to have an A No. 1 track. On the other hand I do not think that the 33-ft. stock rail, with the 33-ft. switch point, will make a bad job, or a job that you would be ashamed to have in your main track at fairly high-speed points, if the switch is properly looked after.

Mr. Berry:—I hope I proved yesterday that I was a good soldier by quitting when I got orders. It occurred to me, after thinking over the matter, that perhaps the Chairman misunderstood what I said in the beginning of my talk yesterday, and that was that while the switch points were under discussion there were probably five members of this Committee who dissented from the conclusions of the Committee. We had already voted and passed upon the question of frogs; we had not heard a word from the dissenting members, and we were rapidly approaching a vote on split switch points without hearing from them. I discovered one of the dissenting members on the floor of the house, and I asked him

afterwards why he did not go up on the platform, and he said, there was no room. As a side issue, let us provide room for the members. He is on the platform this morning, however.

Mr. Chairman, with that understanding I did talk to the point about switch points, but I had this in mind.

The President:—The Chair apologizes to the "good soldier."

Mr. Berry:—The Committee had said that the length of the switch points was so bound up with the question of the numbers of frogs that if you disturb one you would disturb the other, the vote had got past frogs. In my opinion, I thought we ought to give the dissenting members a chance to say something, and while I was not privileged to speak about frogs, as it had passed, I took exception to some of the conclusions and thought the dissenting members might have the same views in regard to the matter, hence went into the frog question first. If I had started on the switch points first and reached the frogs later, I suppose it would have passed through. That was the reason why I thought the five dissenting members ought to have something to say. This Association wants to know everything there is about a subject, so that it can pass upon it intelligently. This Committee were intending to incorporate in the Manual and Proceedings the recommendation in regard to frogs and split switch points, with five dissenting members. To me it is a very important thing what we put in the Manual. We, nearly all of us, in times of doubt, go to the Manual or Proceedings to see what is best to do. As long as the members of this Association do that, outsiders will do it. As an evidence of the effect, of placing matter in the Manual, I would like to read from the Chicago Record-Herald of this morning, under the title, "For Third Rail Plan." It says:

"It is regarded as certain that the standard will be adopted, and its approval will mean that every railroad in the country agrees to the specifications that have been prepared. At the present time some roads have a third rail located several inches from the tracks, a number constructing it at a low level, and others at a much higher level."

You can see what the newspaper says before these Proceedings appear in the Manual, and I know that a great many people outside of this Association take whatever they find in the Manual as the best practice and find fault with other people who do not.

I think we ought to let the five members say something or have their views thoroughly understood.

There is another question. This report says that 55 per cent. of the railroads—not of the mileage—use No. 10 frogs. They do not say anything about the length of switches, but 15 feet is the usual length, so you see there is over one-half of the roads in this Association still using a No. 10 frog, with a split switch presumably 15 feet long. Is it justifiable to go to a 16½-foot split switch and incidentally a No. 11 frog? We can readily see why we go to the shorter split switch and a No. 8 frog, because we have had a great deal of trouble in maintaining a No. 7. We can also understand why it is desirable to use a No. 30 or 33-foot

switch with a 16-foot frog, because they are on high-speed lines, but a 16½-foot split switch with No. 10 frog is a different proposition. We have, none of us, had trouble maintaining them, and it is a question whether we want to change from No. 10 to No. 11 frogs. It was not to find fault, but I wanted these five members to have something to say, so that the Association could vote upon it intelligently.

There is another important thing I would like to bring up. Every railroad in this Association that has from 5,000 to 10,000 miles of railroad, has in stock anywhere from $5,000,000 to $10,000,000 in its supplies. I think everyone will say that the storekeepers and the officers are continually objecting to getting so many different parts. If a No. 15 split switch is good enough and a No. 10 frog, why add, even on new work, No. 11? It makes simply so much additional material to carry in stock, and I thought perhaps this might have been the opinion of the dissenting members, hence I would like to have it clearly brought out by them what their objections are, so that before the vote is taken on the split switches we might understand their objections, and perhaps this Association would like to reconsider its decision upon the frog question after they had heard from the five members.

I like to abide by the decisions of this Association, but I am free to confess, and one of the dissenting members said he thought that this was not the best practice, there are a number of members in this Association who feel the same way. If we are tied down to one thing, with only a single illustration, it may embarrass some of us.

The President:—Do any of the members of the Committee desire to say anything?

Mr. L. S. Rose (Cleveland, Cincinnati, Chicago & St. Louis):—I wish I could talk like Mr. Berry—we could get by with this report. I think the Chairman has explained the dissension of the dissenting members. He has read the letters giving the reasons that they do not care to sign the report in full. He has explained that it is not the question of the length of switches, except in one case, it is some other detail. There is a little difference of opinion as to how this report should be worded. It is a large Committee and practically, as the Chairman says, agrees with the exception of details. One of the dissenting members is here, and I suspect he will talk for himself. It is not a question of safety. The lengths of switches and the numbers of frogs are figured out, we think, on a scientific basis. It is not anything very radical. It will not put anybody in court if they do not adopt it, because it is a question of standards, not of safety. We might have a switch that conformed to these standards that would not be as safe as some switch that did not. It might be a question of the size of the rail or some other detail. I do not think that the safety question can be brought up, it is a question of design. Mr. Berry also says that we carry large stocks. I submit that the frog and switch stocks change very rapidly on a well-regulated railroad. They are worn out. Also we were instructed to give a recommendation for

three lengths of switches, for three numbers of frogs, to keep the stock down, so that when a road adopted this recommendation there would be only three to carry and that would take care of all needs. We tried to give four, but the convention said, "No, only three."

I further think that we have got the best three. No road need change their standards if they do not care to, and they will not get into trouble about it—but we think we have the best three. We can take care of junctions the best that anyone can take care of them, up to our present art. We might change our plan on switches a little; might have curved switches, but we do not think we are up to that yet. The roads do not want to carry so many different kinds in stock. They want a switch that they can use anywhere. A few years ago, I think two or three, a circular was sent out by the International Railway Congress, asking what roads were increasing the speeds at junctions, and nearly everybody made a report. The question of getting trains over the railroads and getting them through junctions quickly, is important; it saves time. The 33-foot switch will take care of that, the No. 16 frog will take care of it. We have one for yards and one for yard turnouts, and I submit it is better to take the recommendation of this Committee than to take some other recommendation that has not been given study.

Mr. George H. Bremner (Chicago, Burlington & Quincy):—This report was very carefully considered by the Committee, and I think the Chairman is to be congratulated that he got as near a unanimous opinion from the Committee as he has, and that the Committee have come as near together as they have in these conclusions.

There is no dissent in the Committee from the fact that the practice recommended in these conclusions is good practice. Conclusion No. 1 is unanimously agreed to. On the other two conclusions there is considerable difference of opinion, as you have heard, and a number of members of the Committee do not agree that they represent the best practice, although they all agree that they represent good practice.

Considering the number of frogs, it is very questionable whether a No. 8, a No. 11 and a No. 15 will fulfill all conditions. It is not likely there are more than two or three, if there are any roads in the country that have frogs of these three numbers as their standard, not but many roads have some of them as standards, but to use the combination as presented by the Committee would probably change the practice of every road in the country to some extent. By a fuller study of the situation on the various roads, a combination of frog numbers might be found which would only change the practice of a part of the roads in the United States and Canada, and still give fully as good results. The frog numbers recommended do not nearly represent the needs common to most roads. The No. 15 frog, for instance, is not the only frog that is used for terminals, nor can it be claimed as the best. Some roads use 20's, some use 24's, some possibly 22's for their ends of double tracks and similar places. Frogs lower than No. 8 are very common, in fact they are gen-

eral in yards where it is necessary to save room and where the work is done by switch engines, so that the limits prescribed by the numbers of the frogs submitted is inside of what is to-day good practice and also, it may be, the best practice. Frogs are all the time becoming sharper on account of the higher speed, heavier and stiffer engines and longer equipment; so that where to-day the Committee recommends a No. 8, a few years ago they would have recommended a No. 6, and a No. 9 will be better in the very near future. Likewise a No. 15 is likely to be replaced by a No. 20, or even higher frog. Practice is constantly changing and track material is being improved very rapidly at the present time.

Concerning the length of switch points, those recommended are good practice, but they are not the only good practice, and the same arguments in regard to their lengths will apply that apply to the numbers of the frogs. There are few roads in the United States to-day that are using 33-foot switch points to a great extent, although they can be used. I note German roads are beginning to use switch points even longer than that. They have been trying switch points with a fixed heel. The heel on all of our switch points is pivoted. By the use of this fixed heel they get a curved switch point, which, if it can be properly made, I think we will all admit is very desirable, and it is very likely to come, if we can find a construction that will make a proper fit for the point against the stock rail. They have a special section of rail for this switch point, and I see no reason why the practice may not become the practice in this country. The use of a special shaped head, and of hardened steel or toughened steel for our points is surely within the lines of reason and economy, if a proper design can be made by which we can get a curved switch point for high-speed trains. Consequently, while this question is open, I think it is proper for this convention to adopt these resolutions, not as the action of the convention as recommended practice to bind the Association, but as good practice which we can agree to but not recommend as the best practice.

Mr. Jenkins:—Mr. Chairman, I wish to call attention particularly to the fact that two of the dissenting members dissented more from the text of the argument than from anything else; that they objected to my introducing matter which weighed against the Committee's report. My intention, and I think the wish of most of the members of the Committee, was to present full information to the Association, so that the subject could have proper consideration, and two of the dissenters simply objected because my argument was not strong enough.

Mr. Rose:—Is there a motion before the house?

The President:—There is a motion before the house for the acceptance of this.

Mr. C. H. Ewing (Atlantic City Railroad):—I would like to ask the Committee if they can advise us the difference in the angle of a 30-foot switch and a 33-foot switch.

Mr. Jenkins:—Just 10 per cent. difference.

Mr. Ewing:—What is that in minutes?

Mr. Jenkins:—It is approximately six minutes.

Mr. L. C. Fritch:—I think perhaps the convention could reach a conclusion, or a unanimous opinion on this subject if the form of the recommendation were changed. It has developed in this discussion that the general practice on main line turnouts is No. 10, and there is a very wide practice in the use of No. 15 on high-speed turnouts. If the recommendations were changed to read something like this: "That for yard work No. 8 frogs are recommended as good practice, for general main line turnouts No. 10 or 11 frogs are considered good practice, and for high speed turnouts No. 15, 16, or a higher number of frogs are good practice." This, however, departs from the instructions of the Committee. The Committee is following its instructions to make recommendations for a minimum number of frogs and switches, to be adopted as good practice, but we have discussed this matter for five or six years and do not seem to be any nearer a conclusion than we were five years ago, and I doubt if we ever will reach a conclusion on three numbers of frogs, or three switches, and I would suggest that this form of recommendation be changed.

Mr. Rose:—I do not think we agree with Mr. Fritch on that.

The President:—It would not be advisable to make any change now, without a motion for reconsideration, because the length of frogs has been passed upon already.

Mr. Rose:—I mean as an argument. I do not think we can agree to put in that sort of a recommendation. We have tried that before, and we have been instructed. I would not agree to that anyway.

The President:—The motion before the house is that the 11, 16½, 22 and 33-foot switch point lengths be adopted and put in the Manual.

Mr. L. C. Fritch:—Was not that amended by changing it to read 11, 16½ and 26?

The President:—It was not seconded, as I recollect.

A Member:—I second it.

The President:—Then the amendment will be put first.

Mr. Rose:—I asked a little while ago if there was a motion before the house and I had in mind Mr. Fritch's motion. I think we should discuss his side of it before we put it to a vote, if that is the question.

The President:—The amendment before the house is that the lengths of 22-foot and 33-foot switch points be combined into one of 26 feet in length.

(The amendment was put to vote and lost.)

The President:—We will now vote on the original motion as stated.

(The vote on the original motion not being definite, a standing vote was called for and 58 voted in the affirmative, 14 opposed.)

Mr. L. C. Fritch:—I move to reconsider the question of the number of frogs recommended by the Committee to be adopted as representing good practice.

(Motion seconded by Mr. Berry.)

The President:—Did the mover of the motion vote for or against the motion as originally adopted?

Mr. L. C. Fritch:—I did not vote on the question of frogs.

(The President put the motion of Mr. Fritch, and it was not adopted.)

Mr. Jenkins:—I move that this conclusion be printed in the Manual, under General Rule 16-g.

In connection with these specifications, I wish to state that these were before the Association last year in a slightly different form. The substance of the specifications is practically the same as that which was considered paragraph by paragraph last year, but it has been rearranged and the general instructions and general specifications combined; we took all reference to frog numbers and length of switch points out of the specifications, so as to have them acted on separately and rejected if the convention saw fit to reject them, without impairing the specifications. The specifications this year, therefore, do not contain the drawings of frogs and switches which they contained last year, at the time they were considered, but the specifications carry with them Fig. 1 on page 381 and Fig. 2 on page 382, showing the planing of the switch point and the details of the point, giving the dimensions of the holes and distances from center to center.

If the convention does not wish to take the time to go through these specifications paragraph by paragraph, as we did last year, we could simply act on it as a whole. I move, in order to save time, that we consider the specification as a whole without reading it paragraph by paragraph.

The President:—In view of the facts stated by the Chairman of the Committee it seems to be a good plan, considering that you have had this Bulletin before you for some time, to take the course recommended by the Chairman of the Committee, and with your consent the Chair will simply ask those who have made up their minds that they want to make some special criticism on some particular paragraph to make such criticism, without the necessity of reading the specifications in detail, after which the specifications will be presented to you as a whole.

Mr. F. J. Bachelder (Baltimore & Ohio):—I would suggest that under "Foot Guards," we add a clause that foot guards shall conform to the requirements of State laws in the States for which the material is ordered. In some States the law specifies a certain type of foot guard.

The President:—Does not that go in any case without saying?

Mr. Bachelder:—It would save time to have it definitely understood.

The President:—Do you make that as a motion?

Mr. Bachelder:—Yes.

(Motion not seconded.)

Mr. Lindsay:—Under "Bolts," the specifications differ from the specifications previously submitted in omitting the "U. S. standard." The previous specification required that the bolts must be round and true to

size, with the U. S. standard square heads and nuts, and the thread should also be specified. I refer to the second paragraph on page 378.

Mr. Rose:—That was done on a motion made by Mr. Ewing. He wanted that cut out so that we could use a special bolt.

The President:—Any additional criticism?

Mr. Lindsay:—I think that the word "spring" should be substituted for the word "wing" at the top of page 379.

Mr. Jenkins:—It may be either "spring rail" or "wing rail," but the Committee will accept the suggestion.

Mr. Lindsay:—On page 381 under Fig. 1 there is a table which shows the length A. B. for the different lengths of switches; figuring that out in feet per inch, the first one is 1 inch in 16 feet, the second one 1 in 12, and the remainder 1 inch in 6⅔ feet. I think the 16-foot 6-inch switch would be very much better if A. B. was longer. I move the substitution of 7 feet for 5 feet in the length A. B. in that switch.

(The motion was carried.)

Mr. Lindsay:—I ask for information concerning Fig. 2, page 382, if the distance A is the theoretical distance or the practical distance?

Mr. Jenkins:—That is the theoretical distance. I will explain that as the heel distance of the switch is 6¼ inches, and the distance of the gage line from the stock rail is ¼-inch, it makes a difference of 6 inches for the length of the switch, consequently the theoretical distance from the bend of the stock rail to the point of switch is just 1/24 the length of the switch.

(The specifications as amended were then put to vote and carried.)

The President:—The Committee is dismissed with the thanks of the Association.

DISCUSSION ON ROADWAY.

(For Report, see pp. 387-400.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON ROADWAY.

W. M. DAWLEY.

The President:—The next is the Committee on Roadway. In the absence of the Chairman, Mr. W. M. Dawley, the Vice-Chairman, will make the opening remarks in regard to the report.

Mr. W. M. Dawley (Erie):—The subjects assigned to the Roadway Committee have not been carried out to a conclusion. There was, for the first subject of discussion, the formula for general application, for determining waterways under various conditions with consideration of the hydraulic features. We have been considering for several years the possibility of preparing or selecting, from various formulæ, in common use, one that should be recommended for general application. The investigation made since the Committee's report to the annual convention in March, 1909, does not warrant the Committee varying from the opinion then expressed and accepted by the Association.

The Committee's work since the twelfth annual convention has been directed toward the consideration rather of the hydraulic features of the culvert, and while some progress has been made, the Committee is not prepared now to make any definite recommendation.

On the second question, "unit pressures allowable on roadbeds of different materials, conferring with the Committee on Ballast," no definite conclusion has been reached, because of a lack of information obtainable. There is nothing published in the way of literature covering the conditions as they exist under the roadbed, that is, defining the bearing power of soils, as we use them in railroad work, and before any conclusion can be drawn it would be necessary to make some full-sized tests, as in actual practice, and measure by some means yet to be determined what actual pressure is transmitted to the roadbed through the ballast, and how it varies, both longitudinally and transversely of the track.

On the third subject, "Report on tunnel construction and ventilation," some information was collected and published merely as information, and the Committee has some other material relating particularly to ventilation of subways in cities, and ventilation of the Hudson and Manhattan tubes, under the Hudson River, but that has not yet been published. The chairman of the sub-committee, Mr. Paul Didier, advises that he has considerable information, but has been unable to work it into shape on account of being so busily engaged in constructing tunnels, he has not had time to theorize.

The fourth subject, "The question of agricultural drainage as it affects railways," the Committee during the past two years collected information

as to the drainage laws of the various states, but has never been able to fix upon a form into which the information can be put so as to make it of value to the Association. The Committee is of the opinion that further work along the line of collecting information as to (*a*) Laws and Assessments is futile because the laws are changing constantly, and because the Committee's information is necessarily general and not subject to application to specific cases without legal advice; and further, questions affecting the laws and assessments are, in all railway organizations, handled by the railway's attorneys. The Committee recommends that it be discharged from further consideration of the subject as to Laws and Assessments.

The recommendation of the Committee on subjects 1, 2 and 3 is that they be reassigned for further consideration, and subject 4 be confined to the benefits the railways will derive by the construction of agricultural drainage ditches and levies.

The Committee has been collecting information for two years for the purpose of formulating a conclusion as to what unit pressures are allowable on the roadbed, and the Committee has come to the conclusion that since the available data treats of the sustaining power of soils below the surface, rather than of that of soils peculiarly exposed as the roadbed is to moisture, to the action of frost, and to the loadings peculiar to train service, it will be necessary to make experiments to determine the magnitude and distribution of the loads transmitted to the roadbed through ballast of various kinds and also to determine by test the bearing power of various materials under varying conditions ordinarily attained in the construction of the roadway.

I would suggest that the Committee on Ties be added to that.

The President:—No action on the part of the Association is necessary, as these are progress reports. The Committee has furnished us a starter for some valuable information in regard to unit pressures, and we will hope for a continuation along that line. The Committee is dismissed with the thanks of the Association.

DISCUSSION ON WATER SERVICE.

(For Report, see pp. 401-428.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON WATER SERVICE.

J. B. Berry. Robert Ferriday. F. E. Schall.
Geo. H. Bremner. C. E. Lindsay. W. F. Steffens.
J. L. Campbell.

The President:—The next Committee is that on Water Service, Mr. Robert Ferriday, Chairman. The Chairman will make the opening remarks in regard to the report.

Mr. Robert Ferriday (Cleveland, Cincinnati, Chicago & St. Louis):—The Committee has no changes to recommend in the Manual until the future policy now under consideration is decided. On the subject of "the design and relative economy of track pans from an operating standpoint," the Committee reports progress.

On the subject of deep well pumps we report merely progress, because the subject has not been developed sufficiently to report otherwise.

On the subject of the use of reinforced concrete for water tanks and supports, this report is submitted as information. The Committee believes it is an interesting and impartial statement of the subject. The field of reinforced concrete is being rapidly expanded, and it may develop that the use of such material for this purpose can be made with no doubt of definite success, but the Committee did not feel prepared to offer conclusions one way or the other until its performance had become more definitely determined.

A sub-committee on water treatment has been made part of the Committee organization for the purpose of keeping that subject alive and reporting any developments. There is nothing to report at this time, but the Committee submits, in Appendix A, for the information of the Association, a paper prepared at its request by J. R. Francis, regarding the unusual occurrence of locomotive boiler corrosion, which followed a partial installation of water softeners. It is quite possible that some conditions may be experienced by our members, under similar conditions, and information regarding the means for overcoming it may be of value.

Your Committee has canvassed the membership for opinions and criticisms of the general specifications of steel tanks submitted last year, and same have been revised. The Committee was anxious to include with the specifications for open-hearth steel also those for a material which would resist rust better than ordinary steel, and they are included as printed in the Bulletin. But through an error the circular issued to the membership failed to include the specifications for refined steel and it has since appeared to the Committee desirable to omit the specifications for refined steel for the present, and with the consent of the convention, the

Committee desires to amend the specifications as follows and to submit same for the Manual.

If there are no objections I would recommend that we take up the specifications for steel tanks, paragraph by paragraph, and I can outline the changes that we desire to make:

(1) Change the title to read as follows: "General Specifications for Steel Water and Oil Tanks."

"1. Ordinary Tanks Defined. Ordinary tanks are those requiring plates not more than 5/8-in. thick.

"2. Scope of Specifications. These specifications cover ordinary steel tanks commonly used by railways for usual service conditions only."

(2) Combine paragraphs 1 and 2 to read: "1. Scope of Specifications. These specifications are intended for steel tanks requiring plates not more than 5/8-in. thick."

(3) Change the numbering of the paragraphs in consequence of consolidating paragraphs 1 and 2.

"3. Quality of Metal. The metal in these tanks shall be a special refined steel or open-hearth steel.

"The special refined steel shall have a tensile strength per sq. in. not less than 50,000 lbs. and an elastic limit not less than 30,000 lbs. per sq. in. It shall contain of

Sulphur	Not more than .02 per cent.
Phosphorus	Not more than .005 per cent.
Carbon	Not more than .02 per cent.
Manganese	Not more than .00 per cent.
Silicon	Not more than .00 per cent.

"The steel shall conform in physical and chemical properties to the specifications of this Association for steel bridges.

"For plates not more than 3/8-in. thick, 5/8-in. rivets shall be used. For thicker plates the diameter shall be 3/4-in."

(4) Change paragraph 3 in the Bulletin to read, "2. Quality of Metal. The metal in these tanks shall be open-hearth steel. This steel shall conform in physical and chemical properties to the specification of this Association for steel bridges."

"4. Loading. The weight of water shall be assumed to be 63 lbs., crude oil 56 lbs., and creosote oil 66 lbs. per cu. ft. Wind pressure, acting in any direction, shall be assumed to be, in pounds, 30 times the product of the height by two-thirds of the diameter of the tank in feet.

"5. Unit Stresses. Unit stresses shall not exceed the following:

(a) Tension in plates, 15,000 lbs. per sq. in. on net section.
(b) Shear in plates, 12,000 lbs. per sq. in. on net section.
(c) Shear on rivets, 12,000 lbs. per sq. in. on net section.
(d) Bearing pressure on field rivets, 20,000 lbs. per sq. in.

"6. Cylindrical Rings. Plates forming the shell of the tank shall be cylindrical and of different diameters, in and out, from course to course.

"7. Workmanship. All workmanship shall be first class. All plates shall be beveled on all edges for caulking after being punched. The punch-

ing shall be from the surface to be in contact. The plates shall be formed cold to exact form after punching and beveling. All rivet holes shall be accurately spaced. Drift pins shall be used only for bringing the parts together. They shall not be driven with enough force to deform the metal about the holes. Power riveting and caulking should be used. A heavy yoke or pneumatic bucker shall be used for power driven rivets. Riveting shall draw the joints to full and tight bearing.

"8. Caulking. The tank shall be made water or oil tight by caulking only. No foreign substance shall be used in the joints. For water tanks, the caulking shall preferably be done on the inside of tank and joint only; but for oil tanks the caulking should be done on both sides. No form of caulking tool or work that injures the abutting plate shall be used.

"9. Minimum Thickness of Plates. The minimum thickness of plates in the cylindrical part of the tank shall not be less than ¼-in. and in flat bottoms not less than $\frac{5}{16}$-in. In curved bottoms the thickness of plate shall be not less than that of the lower plate in the cylindrical part.

"10. Horizontal and Radial Joints. Lap joints shall generally be used for horizontal seams and splices and for radial seams in curved bottoms.

"11. Vertical Joints. For vertical seams and splices, lap joints shall be used with plates not more than ⅜-in. thick. With thicker plates, double butt joints with inside and outside straps shall generally be used. The edge of the plate in contact at the intersection of horizontal and vertical lap joints shall be drawn out to a uniform taper and thin edge.

"12. Rivet Holes, Punching and Pitch. The diameter of rivet holes shall be $\frac{1}{16}$-in. larger than the diameter of the rivets used. The punching shall conform to the specifications of this Association for such work on steel bridges. A close pitch, with due regard for thickness of plate and balanced stress between tension on plates and shear on rivets, is desirable for caulking."

(5) Change paragraph 12 in the Bulletin to read, "11. Rivets, Rivet Holes, Punching and Pitch. For plates not more than ⅜-in. thick, ⅝-in. rivets shall be used. For thicker plates, ¾-in. rivets shall be used. The diameter of rivet holes shall be $\frac{1}{16}$-in. larger than the diameter of the rivets used. The punching shall conform to the specifications of this Association for such work on steel bridges. A close pitch, with due regard for thickness of plate and balanced stress between tension on plates and shear on rivets, is desirable for caulking."

"13. Tank Support. If the tank is supported on steel columns with bracing, the metal in such substructure shall conform to these specifications, and the anchorage and workmanship thereof shall conform to the specifications of this Association for the manufacture and erection of steel bridges."

(6) Change paragraph 13 in the Bulletin to read, "12. Tank Support. If the tank is supported on a steel substructure, the latter shall conform to the specifications of this Association for the manufacture and erection of steel bridges, except that allowance shall be made for wind pressure, but not for impact."

Mr. W. F. Steffens (Boston & Albany):—I should like to ask the Committee why they change from the unit stresses adopted by the Committee on Iron and Steel Bridges?

Mr. Ferriday:—These specifications were drawn up by the Committee with the help of Prof. Pence and Mr. A. F. Robinson, who has built a number of tanks during the last sixteen years.

Mr. Steffens:—I should like to ask the Committee if they would be willing to put that in the shape of a factor, a constant, in other words, against the specifications for steel bridges. It is rather awkward to have two sets of unit stresses, one for bridges and another for tanks.

Mr. Ferriday:—I do not think that would be satisfactory. I do not believe it would be desirable to have to make a computation from the specifications for steel bridges. I see no objection to including them just as given.

The President:—Have you any motion?

Mr. Steffens:—I move that the unit stresses be referred to the corresponding specifications for steel bridges, with a corresponding reduction factor.

The President:—There being no second, we will pass on.

Mr. C. E. Lindsay (New York Central & Hudson River):—Do I understand that the cylindrical sections as required in paragraph 6 alternate, first in and then out?

Mr. Ferriday:—Yes.

Mr. Lindsay:—I think the reference to the specification for steel bridges would require a person to have a full set of the bridge specifications. Why could not these clauses be embodied in the specification?

Mr. Ferriday:—I think it has been the practice of all the committees, for the sake of brevity, to refer to the other specifications, without repeating them in detail. In the case of the Masonry Committee, they refer to the specifications for cement, and that is the reason it was done here.

The President:—Any further discussion on No. 12, as revised?

Mr. Ferriday:—The Committee wishes to make the following change in that paragraph: "12. Tank Support. If the tank is supported on a steel substructure, the latter shall conform to the specifications of this Association for the manufacture and erection of steel bridges."

The President:—Is there any discussion on the revised form of 13?

Mr. Lindsay:—I make the same comment as before. As to Mr. Ferriday's comment about our cement specification, I would say that our cement specification is an entity, it is a complete specification in itself, but the specification for steel bridges goes into a great many things not involved in Water Service, and we would have to go over the specification and pick out the paragraphs here and there, to get what we wanted, and we would have to rearrange them, to get the matter complete.

The President:—Your idea is that if the extract is not too long, it can be embodied in the specifications for ordinary steel water and oil tanks?

Mr. Lindsay:—Yes.

The President:—I think the Committee would accept that general practice.

Mr. Ferriday:—"14. Painting. In the shop the metal shall be cleaned of dirt, rust and scale and, except the surfaces to be in contact in the joints of the tank, shall be given a shop coat of paint or metal preservative selected and applied as specified by the company.

"After being completely erected, caulked and cleaned of dirt, rust and scale, all exposed metal work shall be painted or treated with such coat or coats of paint or metal preservative as shall be selected by the railway company."

Mr. Campbell, Chairman of the Sub-committee which prepared this report, feels that we should not accept Mr. Lindsay's suggestion.

Mr. J. L. Campbell (El Paso Southwestern):—I feel, and I believe it is the feeling of the Committee, that the specification paragraph 13, now paragraph 12, as amended, should stand as it has been amended by the Committee. These are general specifications and they avoid going into specific details, and it appeared to the Committee that by reference to the specifications for steel bridges, the Association has a specification governing the designing and erection of the substructure, which would meet the case. When it comes to the matter of designing a particular structure, as to that particular part of the water tank, the supports, we immediately go into the field of bridge engineering, and we would naturally turn to the specifications for the designing of a steel structure taking stresses similar to those carrying railway trains, and it would seem to the Committee to be a very simple thing merely to refer to these specifications, and that it is not necessary to go into detail and embody these specifications in the general specifications for water tanks. It will considerably lengthen the latter specifications if we do that. The stresses that occur in the substructure are quite different from those in the shell, and it would be necessary for us to include all the specifications covering the designing of columns, and that sort of thing.

Mr. George H. Bremner (Chicago, Burlington & Quincy):—It would seem to be proper to refer to the other specifications printed in the Manual, but the Committee should at the same time give us the location of the specifications and give the numbers or the paragraphs in the bridge specifications that are needed to complete the water and oil tank specifications, so that they can be readily accessible to the members without going through the entire bridge specifications.

Mr. F. E. Schall (Lehigh Valley):—Do I understand that the columns for steel substructure of tank are to be designed under the requirements of specifications for steel railroad bridges? No indications as to requirements for compressive unit stresses are given. The tank proper is to be designed for unit tensile stress of 15,000 lbs. per square inch, or about 50 per cent. higher than is allowed for railroad bridges, not considering impact; this unit stress in my judgment is about right; the compression unit stresses should be gaged in the same manner.

The President:—The Committee intends to recommend that the substructure shall be designed in accordance with the specifications for steel bridges.

Mr. Schall:—The specifications are not clear as to this requirement. The compression unit stresses for steel bridges are based on impact being added to stresses.

The President:—That section was changed to read as follows: "If the tank is supported on a steel substructure the latter shall conform to the specifications of this Association for the manufacture and erection of steel bridges." That is the recommendation of the Committee.

Mr. Schall:—What is the reason for allowing a practically 50 per cent. increase in tension stresses for tanks over those allowed for in steel bridges (excluding impact in the latter), and building the columns under the unit stresses for steel railroad bridges making the columns heavier than they need be?

Mr. Ferriday:—I do not believe I quite understand the point. The unit stresses given in paragraph 5 are intended to cover the tank.

Mr. Schall:—The Committee provides for a specific unit stress in tension for the shell of the tank, based upon a static load, and intends to apply for the column supports the unit stresses of steel railroad bridges which are based upon addition of impact.

The water tank specifications are not complete without providing a clear requirement for compression unit stresses and also providing unit stresses for shop and field rivets.

Mr. J. L. Campbell:—That is quite true, and the Committee took that into consideration. The members of such substructure will be light in many cases, and it requires a certain thickness of metal for a proper margin against corrosion and for other considerations, and the Committee believes it will be found that the substructure for a water tank designed in accordance with the specifications for steel bridges will not be expensive in the use of material, and will not put more material in the substructure than should be there in any case.

Mr. J. B. Berry (Chicago, Rock Island & Pacific):—I suggest the preparations of plans and specifications as to tools for erection, and I do it for this reason—when we started to equip our line with steel tanks, it had to be done by division forces. We looked everywhere as to the best and most economical plan to erect the tanks. We finally got up a set of drawings of tools, and had them criticized. I believe it would be a good thing for this Committee to collect such information and recommend the best class of tools for the erection of such tanks, so that the members of the Association will have the benefit of that information.

Mr. Ferriday:—I move that the specifications for steel water and oil tanks, as amended, be adopted and included in the Manual.

(The motion was put to vote and carried.)

The President:—The Committee is dismissed with the thanks of the Association.

DISCUSSION ON CONSERVATION OF NATURAL RESOURCES.

(For Report, see pp. 429-458.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON CONSERVATION OF NATURAL RESOURCES.

WILLIAM MCNAB.

The President:—The first business this morning will be the report of the Committee on Conservation of Natural Resources, Mr. E. O. Faulkner, Chairman. In the absence of Mr. Faulkner, the report will be presented by Mr. McNab, the Vice-Chairman.

Mr. William McNab (Grand Trunk):—I regret very much the absence of the Chairman of this Committee, Mr. Faulkner. As his immediate deputy, however, I will say that the compilation of this report has given the Committee a great deal of pleasure. It is submitted at present merely as a report of progress and for information, but it is the purpose of the Committee to continue the work on the present lines, by keeping in touch with the National organization in the United States, as well as with a similar one in the Dominion of Canada.

The President:—The Committee simply reports progress and the Committee is dismissed with the thanks of the Association. They have given us a lot of splendid information in their report and we feel very grateful to them.

DISCUSSION ON MASONRY.

(For Report, see pp. 459-504.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON MASONRY.

A. W. Carpenter.	C. E. Lindsay.	E. V. Smith.
R. D. Coombs.	Hunter McDonald.	G. H. Tinker.
L. G. Curtis.	P. C. Newbegin.	E. E. R. Tratman.

The President:—The next report is that of the Committee on Masonry, of which Mr. G. H. Tinker is Chairman. Mr. Tinker will make the opening statement.

Mr. G. H. Tinker (New York, Chicago & St. Louis):—The Committee on Masonry held four meetings during the year, all at Chicago. The Board of Direction assigned six subjects for its investigation and also directed that the Committee appoint sub-committees to act with the Joint Committee on Concrete and Reinforced Concrete and the Joint Committee on Uniform Specifications for Portland Cement.

The various subjects have been assigned to sub-committees and work has proceeded upon all subjects. In accordance with the directions of the Board, we present final reports upon two subjects only; upon a third subject, the waterproofing of masonry, we submit abstracts of the replies received to a circular sent out by the Committee. This is presented as information at the present time, it being the intention of the Committee to follow the matter up with a final report at a later date. This subject the Committee has had under consideration for several years, during which time it has been engaged in collecting data upon which to base a final report.

Upon the subject of "Methods of Patching and Repairing Plain and Reinforced Concrete," the matter presented by the Committee will be found on page 474. The Committee sent out a circular of inquiry upon this subject and received a great many replies, over one hundred, in fact. There were so many replies, a number of them describing practically the same method of work, that only a selection has been presented in the form of abstracts to show the substance of the information received. The conclusions of the Committee upon this subject are given on page 476. There are seven conclusions. The Committee asks that these conclusions be approved under Rule 16-g for publication in the Manual.

"Your Committee presents the following conclusions as to the methods of repairing defective or worn surfaces of concrete:

"(1) In all cases the surface to be repaired must first be thoroughly cleaned of all loose material, laitance and dust and the clean, rough, sound concrete exposed to receive the patch. Probably the best method of cleaning is by means of a steam jet.

"(2) After cleaning, the surface to be repaired must be thoroughly saturated with water, not simply moistened, but so thoroughly drenched that the old concrete will not absorb water from the new mortar or concrete used in patching. If possible, the surface should be kept covered with water for several hours.

"(3) If the repair or patch is to be made on a vertical or sloping surface and is not to be more than 1½ in. thick, the surface of the old concrete, while it is still wet, should be spattered or splashed with a cement grout, following this immediately with a fairly stiff plaster coat of mortar made of the same proportions of cement and sand as was used in the original concrete, but never richer than 1 cement to 2½ sand. This plaster coat should not be thicker than ½-in. and each coat should be forced into the surface, but not dragged with a trowel. The surface of each coat, except the final coat, should be "scratched" to give a bond for the next coat. This plastering should preferably begin at the top and progress downward, and only enough time be allowed to permit each coat to receive its initial set before the next coat is applied. The final coat should be finished with a wooden float and only enough water used to properly finish the surface. This patch should be kept damp and protected from sun or frost till fully set up.

"(4) If the repair or patch or 'finish coat' is to be made on a horizontal or nearly horizontal surface, the surface of the old concrete should be slushed and broomed with a thin cement grout, following this immediately with a *wet* mortar made of 1 part cement and 2½ parts sand or granite screenings and of the full thickness required (not less than ½-in. thick, however). When this mortar begins to take its initial set, it should be floated or troweled to such a finish as may be desired."

Mr. P. C. Newbegin (Bangor & Aroostook):—Referring to Conclusion 4 as to the methods of repairing defective or worn surfaces of concrete, I ask why in one case the Committee recommends mortar of the same standard as the original structure and not in the other?

Mr. Tinker:—There is no very good reason for the difference, except that in the case of a horizontal surface there is not the tendency for the mortar to fall off that there is on a vertical surface. In both cases a very rich mortar is not successful. It cracks too much. Therefore, we limit it to 1 to 2½. There is less cracking and less shrinkage if the two mortars are of the same consistency.

(Conclusion 4 was adopted as presented.)

Mr. Tinker:—"(5) If the repair or patch is to be made on a vertical or sloping face and is to be more than 1½ in. thick, it will be advisable to embed dowels into the old concrete, as deeply as the thickness of the proposed patch, and spaced sufficiently close together to firmly anchor the patch to the old concrete. The dowels must be wedged into the old concrete and it will be advisable to fasten wires, metal fabric or bars to the dowels, in the case of extensive patching, as an additional safeguard. The patching may then be done with mortar without forms, or with wet

concrete supported by forms, depending upon the thickness and the extent of the patch.

"(6) If the repair or patch is to be made on a horizontal or nearly horizontal face and of considerable thickness, dowels may be used, or the concrete may simply be reinforced by fabric or bars without using dowels—treating the patch as a block of masonry."

Mr. A. W. Carpenter (New York Central & Hudson River) :—Does paragraph 6 refer to patches more than 1½ inches thick? The preceding paragraph refers to a patch more than 1½ inches thick. Paragraph 6 does not give any definite thickness.

Mr. Tinker:—This refers more especially to a rather thick block of concrete, in the nature of a replaced bridge seat, which might be from 6 inches to 2 feet thick. In that case it goes a little outside of the designation of a patch.

Mr. E. V. Smith (Baltimore & Ohio) :—I notice that in paragraphs 5 and 6 there is no mention of the size of the dowel or the number of dowels to be put in. I ask the Committee if they considered that?

Mr. Tinker:—That would be regulated by the size of the patch, and the method to determine that would be to consider the cross-section of the patch and the amount of shrinkage stress which could be obtained, putting in dowels enough to withstand the shrinkage stress.

(Conclusion 6 was adopted as presented.)

Mr. Tinker:—"(7) Care must be taken not to have thin edges on patches. To avoid this, it may be necessary to cut out sound concrete around a place to be patched, so as to give deep edges to the patch. If possible, the edges should be undercut."

(Conclusion 7 was adopted as presented.)

Mr. Tinker:—The second subject upon which we present conclusions is upon "Methods of Depositing Concrete Under Water."

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis) :—Mr. President, pardon me, but before we take up the consideration of methods of depositing concrete under water, I wish to ask the Committee a few questions relating to this matter of patching concrete. I want to know if the Committee has made any investigation of the different patented methods that are being so extensively advertised, and I refer especially to one which seems to be a modification of what is known as the old rust joint, a mixture of emery grindings, Portland cement and salamoniac. The percentages, I believe, are about 49 of iron filings, 49 of Portland cement and 2 of salamoniac. The mixture has been patented, and the manufacturers are endeavoring to sell it at the rate of 5 cents a pound. They produce samples of the effects and efficiency of the method, and I want to know if that method, or any other of the various mixtures, have been brought to the attention of the Committee, and whether they gave them consideration and decided to turn them all down.

Mr. Tinker:—This Committee has not considered definitely mixtures of that kind, perhaps for the reason that the attention of the Committee

was not called to them, at least until after the report had been formulated.

I may say, in general, that the Committee is inclined to frown on patented mixtures. The Committee does not believe in them. In this part of our report we refer to the patching of concrete. The mixture to which Mr. McDonald has referred is in the nature of a foreign substance which is placed upon the concrete. It is not, strictly, a patch. There are a number of substances which can be made to adhere to the surface of concrete and produce a different finish. For instance, on a concrete floor, there are a number of substances which will make a more or less ornamental finish, but they are not strictly patches. The idea of a patch is that a concrete surface which is either imperfect or broken, must have its surface restored, by putting a patch of concrete upon it.

Referring to the patent mixtures, this particular mixture, as has been said, is about one-half Portland cement, about one-half iron filings and a small percentage of salamoniac, all comparatively cheap materials, and it is being sold at five cents a pound. If the cost of Portland cement by the pound is computed it will be seen that the cost of this mixture at five cents a pound figures out about 15 times the cost of Portland cement. That may be one reason why we did not consider it. Portland cement is plenty good enough.

Mr. McDonald:—I did not know that the Committee expected this section to be confined to the method of patching concrete with concrete. If they are convinced that they have arrived at the best method of patching concrete and the plan they propose is all right and will work in all cases, then I think the Committee's report is proper. On the other hand, if there are patented methods of patching worn places in concrete surfaces that are superior to the method recommended by the Committee, I think we ought to know it whether they are patented or not.

Mr. L. G. Curtis (Baltimore & Ohio):—I inquire if the Committee has made any use of what is known as Ransomite for the preparation of the surface of concrete before the application of the new surface is made. The Baltimore & Ohio has used a great deal of it, with good success, so far as my information and experience goes, and I would like to inquire as to that point.

Mr. Tinker:—In the abstracts of the replies to our circular which we give in the report, there will be found a number of methods recommended for preparing the surface of the concrete, one of which is the acid method, which is a good method. I understand that the use of the Ransomite mixture is an acid method of treating the surface of the concrete. The Committee has said nothing about that in the conclusions. It is referred to in the preliminary discussion. The Committee recommends, as the best method, the use of a steam jet.

The President:—We will now proceed to the consideration of the methods of depositing concrete under water.

Mr. Tinker:—Five items were considered under this head: Methods used for depositing concrete; depth of water; results; precautions neces-

sary to secure desired results; statement of the cost of plant and relative cost of depositing concrete per cubic yard.

Upon the last item not much information was obtained, for the reason that many railroads do not have these costs. The work is often done by contract and the cost is not available, and if the work is done by the company forces, the cost is often obscured, so that it is not easily obtained. There is some little information upon this point which will be found in the abstracts of the replies.

"(1) Concrete may be deposited successfully under water, if so handled as to prevent the washing of the cement from the mixture.

"(2) Cofferdams should be sufficiently tight to prevent current through the pit, and the water in the pit should be quiet.

"(3) The concrete should be deposited in place either by means of a drop-bottom bucket or a tremie, and should not be allowed to fall through the water."

Mr. C. E. Lindsay (New York Central & Hudson River):—Does that section exclude all the other methods, confining us to the drop-bottom bucket or a tremie?

Mr. Tinker:—It does not exclude the other methods. There are situations where the other methods may be used, but we do recommend, from the information received, especially for a work of magnitude, that these two methods are preferable. One of these methods may be preferred in one case and the other method in another case.

Mr. Lindsay:—I had in mind some work on a bridge, where we had riprap that was torn loose, and we put the concrete down dry, in sacks, in sixteen feet of water, with *quite* a strong current flowing, and got very good results.

Mr. Tinker:—"(4) Where a bucket is used, it should be carefully lowered to the bottom and raised to the surface, so as to cause as little disturbance as possible of the water.

"(5) Where a tremie is used, it should be kept filled with concrete up to the top of the water level, and the discharge end should be kept buried in the freshly deposited mass to prevent emptying, and raised a few inches at a time as the filling progresses.

"(6) The surface of the concrete must be kept as nearly level as possible to avoid the formation of pockets which will retain laitance and sediment.

"(7) Where concrete is not deposited continuously, all sediment should be removed from the surface of the concrete, by pumping or otherwise, before depositing fresh concrete.

"(8) The concrete should be a 1:2:4 mixture and of a 'quaking' consistency."

Mr. R. D. Coombs (Consulting Engineer):—If conclusion No. 1 is retained, should it be necessary to specify the exact mixture in No. 8, and would it not be possible in some cases to use a leaner mixture?

Mr. Tinker:—It is undoubtedly true that concrete of a different mixture, or leaner mixture, might be successfully used. The danger with

concrete under water is that some of the cement will be washed out, and for that reason the mixture should be fairly rich. The Committee thought 1:2:4 is fairly rich, and perhaps not too rich.

"(9) Freshly deposited concrete should not be disturbed.

"(10) Where the flow of water through the pit cannot be prevented, concrete should be deposited in cloth sacks."

Mr. E. E. R. Tratman (Engineering News):—The wording of conclusion No. 10 does not seem to cover work which is done in open water. The use of the words "through the pit" seems to imply work done in a cofferdam. A large amount of work, both on the lakes and the seacoast, is done in open water, such as pier and harbor work. I would suggest the words "in open water or" be prefixed to the present conclusion, so that it will read, "In open water or where the flow of water," etc.

(On motion, duly carried, the conclusions were adopted as a whole.)

Mr. Tinker:—The Joint Committee on Reinforced Concrete expected to have a final report in print at this time, but it has not yet been published. The Joint Committee on Uniform Specifications for Cement had several meetings and finally failed to agree. The Departmental Committee of the Government has adopted a specification, and the American Society of Civil Engineers has adopted its own specification.

The work of this Committee was brought to a close too late to do anything more than make a statement of it in the report. It would be desirable to have the Committee take the subject up for further consideration and make a report next year.

That covers the work of the Committee, and we ask that the conclusions adopted be printed in the Manual under Rule 16-g.

(The motion was carried.)

The President:—The Committee is dismissed with the thanks of the Association and commended for their excellent work.

DISCUSSION ON RECORDS AND ACCOUNTS.

(For Report, see pp. 505-507.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON RECORDS AND ACCOUNTS.

H. J. PFEIFER.

The President:—The next report is that of the Committee on Records and Accounts, of which Mr. H. J. Pfeifer is Chairman. The Chairman will make the preliminary statement.

Mr. H. J. Pfeifer (Terminal Railroad Association of St. Louis):—The Committee was directed to make comprehensive studies of the forms in the Manual, and of the economical way of managing a storehouse. We recommend no changes in the Manual. The Committee devoted practically all of its time to the study of the storehouse proposition. The first question that presented itself was: Should the Committee study only the internal economy of the storehouse, or should it also take into consideration its relation to the other departments of the railroad? From the standpoint of Maintenance of Way Department, it seemed that the latter view was the correct one. The Committee offers its conclusions shown on page 506, and I move their adoption.

"It is recommended—

"(1) That no changes be made in the forms appearing in the Manual.

"(2) That the following statement embodies the general principles governing the economical management of a railway storehouse:

"REASONS FOR MAINTAINING A STOREHOUSE.—The object of a storehouse is to provide material and tools when required so that the cost of work may be a minimum, bearing in mind the factors of delay to work or labor, also interest on investment in stock.

"The following essential elements enter into the problem:

"(a) STANDARDIZATION.—The standardization of materials and instructions in regard to their use will reduce to a minimum the number of items of material of the various classes which should be carried in stock. The amount of each item which should be carried in stock will depend upon the rate of consumption, time required for the purchase and delivery of material, and also upon local conditions.

"(b) CLASSIFICATION OF MATERIAL.—This is necessary so as to reduce to a minimum the cost and time of handling. An approved classification should be followed in making requisitions.

"(c) STOCK ACCOUNT.—An account should be kept of stock showing at all times a record of receipts, disbursements and amount on

hand. Stock should be replenished when the amount of any item has been reduced to a fixed minimum. Inventories should be made at stated periods. A proper stock account furnishes a check on excessive supply and obsolete material.

"(d) DISTRIBUTION.—When material is shipped, notice should be sent to consignee showing partial or complete filling of requisition and, if partial, when final shipment may be expected.

"(e) ORGANIZATION.—The storekeeper's place in the general organization should be so fixed and adjusted that the measure of his efficiency is, primarily, the promptness and accuracy with which he fills requisitions, and, secondly, his ability to hold down the stock investment to the lowest amount consistent with the first requirement."

(The motion was carried.)

The President:—The Committee is dismissed with the thanks of the Association.

DISCUSSION ON ELECTRICITY.

(For Report, see pp. 509-558.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON ELECTRICITY.

J. R. W. AMBROSE.
F. J. BACHELDER.
W. S. BOUTON.
R. D. COOMBS.
L. C. FRITCH.
J. B. JENKINS.
E. B. KATTE.
GEORGE W. KITTREDGE.
J. H. MILBURN.
G. A. MOUNTAIN.
H. J. PFEIFER.
A. F. ROBINSON.
EARL STIMSON.

The President:—The next report is that of the Committee on Electricity, of which Mr. George W. Kittredge is Chairman.

Mr. George W. Kittredge (New York Central & Hudson River):—This Committee, following out the instructions of the Board of Direction, has carried to a conclusion two recommendations, the question of clearances, and transmission line crossings.

The Committee felt, until quite late in the year last past, that it was going to have difficulty in presenting conclusions on these two subjects, which would be satisfactory, and it was only at the very last meeting that the matter was cleared up in such a way as to enable us to unite in making reports which we believe will be acceptable to the Association and the public generally.

Our recommendations are contained on page 511. I move the definition of "Third Rail Gage," reading as follows, be adopted and inserted in the Manual:

"(1) Definition: 'Third Rail Gage. Distance measured parallel to plane of top of both running rails between gage of nearest running rail and inside gage line of third rail.'"

(The motion was carried.)

Mr. Kittredge:—The second recommendation is the adoption of the lines shown on diagram "A" as equipment clearance lines.

I move the adoption of recommendation 2.

Mr. J. B. Jenkins (Baltimore & Ohio):—I understand that Mr. Milburn, of the Baltimore & Ohio, has something to say on that recommendation.

Mr. J. H. Milburn (Baltimore & Ohio):—In taking up the question of clearance for the Baltimore & Ohio System, and trying to establish a standard for our use, I considered the diagram as presented by this Committee, and found that the line which is represented on this diagram as suggested for design of equipment was a line that, if adhered to, would put out of business some of the rolling stock which we have to handle, not only of the Baltimore & Ohio, but of other companies. Our third rail is a short distance above the running rail and level top contact. and

we have had cases where rolling stock has injured the corner of the covering of the third rail, which is some distance outside of the lines proposed here for third rail construction. I had no intention of making any remarks on this, but being called to the floor I have said what I did because I think this diagram is pretty liberal from a third rail point of view and not quite as liberal as it should be from a motive-power point of view.

Mr. L. C. Fritch (Chicago Great Western):—The Baltimore & Ohio is represented both on this Committee and on the Committee of Clearances of the American Railway Association, so that any objections which the Baltimore & Ohio had were taken under consideration. I do not know whether the Chairman has stated that this diagram will also be presented to the American Railway Association, by its Committee, at the next meeting of that Association, so that if this Association adopts this clearance diagram it will be in harmony with the American Railway Association report.

Mr. W. S. Bouton (Baltimore & Ohio):—I ask if the diagram which goes below the top of the rail conflicts with the timber guard rail on bridges?

Mr. Kittredge:—The diagram shows that the clearance for equipment does not come below the timber guard rail. We are discussing the clearance line for the design of equipment.

(The recommendation was adopted as printed.)

Mr. Kittredge:—"(3) The lines shown on diagram 'A' as permanent way structure adjacent to third rail clearance lines.

"(4) The lines shown on diagram 'A' as third rail structure clearance lines.

"(5) The adoption of the specifications for overhead crossings of electric light and power lines."

I want to say a word or two in regard to this report and to lay before the Association the matter as it stands at the present time. Within the last four months the four Associations—the National Electric Light Association, the American Institute of Electrical Engineers, the American Electric Railway Association and the Association of Railway Telegraph Superintendents—acting jointly, have made a report which corresponds very nearly with the report of your Committee. There are differences between the report of the Joint Committee of these four Associations and our report in paragraphs 10, 13, 18, 24, 29, 31, 32, 34, 45, 49, 51, 55, 60 and 61. In some of these paragraphs the changes are simply those of words. In one case the word "practicable" is used for the word "possible," and in another place where it says "Treated poles are recommended," it really means that where wooden poles are to be used, they shall be treated. In all cases of difference the phraseology in our report is the better, we think.

The reason it pleases me to dwell so much on this subject is that it is a very great advantage to have a report which will be accepted and

acknowledged by the principal societies, associations and companies interested. As it is now, particularly in the State of New York, the railways can control the crossings over their rights-of-way, but they have very little to say about crossings which occur in highways. The crossing companies have rights which apparently are co-extensive with those of the railways and almost any old thing does for a crossing in a highway. It is, of course, very desirable, in the first place, that we get safety, and in the second place good construction at highways as well as at private crossings.

We believe that if we will accept their report, using their phraseology, we will be in a very much better condition than if we do not. Some of the members of the Joint Committee were brought into line only after a great deal of hard work and they have shown a disposition to negative their whole joint work and let things stand as they are at the present time, if this Association does not accept specifications which are the same as theirs. How much truth there is in that and what would actually happen is only a matter of conjecture. It is therefore a question of policy whether or not in matters of secondary importance we shall accept their figures and specifications rather than our own.

The President:—We will now take up the "Specifications for Overhead Crossings of Electric Light and Power Lines," by paragraphs. If Mr. Osgood is present, we will be glad to have him enter into the discussion.

The Secretary:—"1. Scope. These specifications shall apply to overhead electric light and power line crossings (except trolley contact wires), over railroad right-of-way, tracks, or lines of wires; and, further, these specifications shall apply to overhead electric light and power wires of over 5,000 volts constant potential, crossing, or constructed over telephone, telegraph or other similar lines.

"2. Location. The poles, or towers, supporting the crossing span preferably shall be outside the railroad company's right-of-way.

"3. Unusually long crossing spans shall be avoided wherever practicable.

"4. The poles, or towers, shall be located as far as practicable from inflammable material or structures.

"5. The poles, or towers, supporting the crossing span, and the adjoining span on each side, preferably shall be in a straight line.

"6. The wires, or cables, shall cross over telegraph, telephone and similar wires wherever practicable.

"7. Cradles, or overhead bridges, shall not be used.

"8. Clearance. The side clearance shall be not less than 12 feet from the nearest rail of main-line track, nor less than 6 feet from the nearest rail of sidings. At loading sidings sufficient space shall be left for a driveway.

"9. The clear headroom shall be not less than 30 feet above the top of rail under the most unfavorable condition of temperature and loading.

For constant potential, direct-current circuits, not exceeding 750 volts when paralleled by trolley contact wires, the clear headroom need not exceed 25 feet."

Mr. G. A. Mountain (Canadian Railway Commission):—I ask the Committee in that connection what they do with trolley wires. I see they except trolley contacts in clause 1; with reference to the clearance of 25 feet, have they any recommendation to make on that?

Mr. Kittredge:—We have no recommendation about that.

The Secretary:—"10. The clearance of alternating-current circuits above any existing wires, under the most unfavorable condition of temperature and loading, shall be not less than 8 feet wherever practicable. For constant potential, direct-current circuits, not exceeding 750 volts, the minimum clearance above telegraph, telephone and similar wires may be 2 feet with insulated wires and 4 feet with bare wires.

Mr. Kittredge:—The only difference in this paragraph and that of the joint report is the word "practicable" in the third line. The joint report uses the word "possible."

Mr. R. D. Coombs (Consulting Engineer):—As I understand it, the request of the Committee is that the Joint Committee report be adopted in order to conform to what has already been done by the other associations and by the Telephone and Telegraph Companies.

Mr. Kittredge:—I would move, for the sole purpose of getting a contract which is similar in all respects, that we adopt the word "possible" instead of the word "practicable." We think that the advantages to be derived from having a uniform contract in this particular outweigh the disadvantages of having one in which one word is not as good as some other word.

(The motion was carried.)

The Secretary:—"11. The separation of conductors carrying alternating current, supported by pin insulators, for spans not exceeding 150 feet, shall be not less than:

Line Voltage.	Separation.
Not exceeding 6,600 volts	14½ in.
Exceeding 6,600, but not exceeding 14,000	24 in.
Exceeding 14,000, but not exceeding 27,000	30 in.
Exceeding 27,000, but not exceeding 35,000	36 in.
Exceeding 35,000, but not exceeding 47,000	45 in.
Exceeding 47,000, but not exceeding 70,000	60 in.

"For spans exceeding 150 feet the pin spacing should be increased, depending upon the length of the span and the sag of the conductors.

"NOTE.—This requirement does not apply to wires of the same phase or polarity between which there is no difference of potential.

"With constant potential, direct-current circuits not exceeding 750 volts, the minimum spacing shall be 10 in."

Mr. H. J. Pfeifer (Terminal Railroad Association of St. Louis):—I notice that the maximum line voltage is 70,000 volts. The Terminal

Railroad Association now has an application for a crossing over its right-of-way, carrying 100,000 volts. I would like to know what provision should be made in a case of that kind.

Mr. Kittredge:—The Committee has not discussed that. It might come up for discussion next year.

Mr. J. R. W. Ambrose (Grand Trunk):—I was just going to bring up the same point. We have several crossings to-day of 110,000 volts.

The President:—That seems to be a subject for further consideration on the part of the Committee.

The Secretary:—"12. When supported by insulators of the disc or suspension type, the crossing span and the next adjoining spans shall be dead-ended at the poles, or towers, supporting the crossing span, so that at these poles, or towers, the insulators shall be used as strain insulators.

"13. The clearance in any direction between the conductors nearest the pole, or tower, and the pole or tower shall be not less than:

Line Voltage.	Clearance.
Not exceeding 10,000 volts	9 in.
Exceeding 10,000, but not exceeding 14,000	12 in.
Exceeding 14,000, but not exceeding 27,000	15 in.
Exceeding 27,000, but not exceeding 35,000	18 in.
Exceeding 35,000, but not exceeding 47,000	21 in.
Exceeding 47,000, but not exceeding 70,000	24 in.

Mr. Kittredge:—That paragraph varies from the report of the Joint Committee as shown on page 522 in that our report contains one more division. The Joint Committee's report, first line, says, "not exceeding 14,000 volts, 9 inches." We have "not exceeding 10,000 volts, 9 inches," "exceeding 10,000, but not exceeding 14,000, 12 inches." After discussion, and for the reasons indicated in discussing paragraph 10, your Committee recommends the adoption of paragraph 13, as shown on page 522, and I so move.

(The motion was carried.)

The Secretary:—"14. Conductors. The normal mechanical tension in the conductors generally shall be the same in the crossing span and in the adjoining span on each side, and the difference in length of the crossing and adjoining spans generally shall be not more than 50 per cent. of the length of the crossing span.

"15. The conductors shall not be spliced in the crossing span nor in the adjoining span on either side.

"16. The method of supporting the conductors at the poles, or towers, shall be such as to hold the wires, under maximum loading, to the supporting structures, in case of shattered insulators, or wires broken or burned at an insulator, without allowing an amount of slip which would materially reduce the clearance specified in paragraphs Nos. 9 and 10.

"17. Guys. Wooden poles supporting the crossing span shall be side-guyed in both directions if practicable, and be head-guyed away from

the crossing span. The next adjoining poles shall be head-guyed in both directions.

"18. Strain insulators shall be used in guys from wooden poles carrying any power wire of less than 6,600 volts, provided the guys are not through grounded to permanently damp earth. Strain insulators shall not be used in guying steel structures, nor required on wooden poles carrying wires, all of which are 6,600 volts or more, provided the guys are through grounded to permanently damp earth."

Mr. Kittredge:—This paragraph varies from the paragraph of the Joint Committee in that beginning on the second line we have inserted the words, "Provided the guys are not through grounded to permanently damp earth," and at the end of the paragraph we have added the words "provided the guys are through grounded to permanently damp earth."

This paragraph is so important that we could not change it. In a conference which lasted over an hour, Mr. Osgood, the Chairman of the Joint Committee, led me to believe, in fact he finally told me, that he would undertake to have his associates adopt No. 18 as written by us provided we would adopt the others as written by him. I move the adoption of paragraph 18 as written here.

(The motion was carried.)

Mr. R. D. Coombs:—I assume that this would be the proper time to read a letter to the Association on behalf of the Joint Committee. The Joint Committee was organized by placing on the Committee of the National Electric Light Association the Chairman of the corresponding committee of each of the associations interested, so that one Committee could do the work, and therefore, when we speak of the Committee of the National Electric Light Association, it refers to the Joint Committee and their report.

The letter which I shall now read for Mr. Farley Osgood was written before the action of the Committee to-day was known:

"The action of the Committee on Electricity of the American Railway Engineering and Maintenance of Way Association in not unanimously approving and formally recommending for adoption the Overhead Crossing Specification, as drawn by the Joint Committee appointed for that purpose, leads me, as Chairman of the Joint Committee, to call to your attention some important facts concerning the specification and action on the same by other Associations in the hope that the matter may be reconsidered by your Association, with a view of establishing this year a national standard specification for crossings of overhead lines, which will become a fact if your Association, also a participant in the formulation of the work, and the last one to act, and the only one up-to-date to disagree, can so adjust its desires concerning changes in the specification, as to make it possible for them to adopt it now, as written, for the sake of unanimity of action just at this time.

"The specification, as written, has been formally ratified and adopted by the National Electric Light Association; American Institute of Electrical Engineers; Association of Railway Telegraph Superintendents; Engineering and Standards Committee of the American Electric Railway Engineering Association, the matter now being up for letter ballot by that Association, requiring under their rules a delay of one year; American

Telephone and Telegraph Company; Western Union Telegraph Company; Postal Telegraph-Cable Company. The Sub-committee on Crossings of the Committee on Electricity of the American Railway Engineering and Maintenance of Way Association has recommended the adoption of the specification to the general Committee on Electricity.

"In view of these facts, there was not the least doubt in anybody's mind as to the formal adoption by the General Committee on Electricity of the specification as recommended by their own sub-committee, whose Chairman was a member of the Joint Committee which formulated the specification, and we learn with much regret that your Sub-committee Chairman is obliged to report that your Committee, even now, feel that a few changes should be made before final approval for adoption.

"For convenience of discussion and examination, we attach hereto a list of clauses of the specification which were recommended by your Committee for change, and for convenience sake, we have listed both the specification, as written, clauses and suggested changes in two ways; one of the lists showing the changes written into the clauses in red ink, and the other list showing the sections side by side in parallel columns.

"A study of the changes recommended brings out the rather remarkable fact that alterations are recommended in only thirteen paragraphs out of a specification of some twenty-eight printed pages, and the Joint Committee which formulated this specification originally honestly believes that the differences between the specification as written and as suggested are so slight, in that they are of no great engineering importance, that on a careful reconsideration of this matter by the Committee on Electricity, they may find it possible to waive their objections for the moment, and recommend for formal adoption this specification as written, in order that all the Associations represented in the Joint Committee may accept the work and launch it as a national standard.

"The Joint Committee does not feel that the suggested changes, as indicated in the attached lists, are in any way improper or undesirable, and in fact, a number of them, we believe, may improve the specification, especially in clearness of expression, but do not feel that the structural results are materially altered, and certainly are not sufficiently changed to be a reason for preventing the universal adoption of the specification.

"The list of names of the Joint Committee shows that the men forming the same are of very wide experience in the field of work under discussion, and are representative of all conflicting interests in overhead construction work, and the fact that so many engineers have agreed upon a specification mutually in Committee, and the fact that the Associations and large companies represented by these men have approved the specification, is a very strong indication that the specification must be a good one and sufficiently safe for our mutual purposes, and it is such a great improvement over anything which has ever before been offered that we feel it our real duty to ask you to reconsider this matter in the broadest possible way, and in fairness to the national overhead construction situation, as a whole, which represents a vast number of conflicting interests of which the steam railroads are one, and an important one, although many of the other large interests, the Committee believes, are quite as important, both from an engineering and financial standpoint, and, therefore, we feel that their judgment in formally adopting the specification drawn by their representatives should have a great deal of weight with your Association, our last member of the General Committee to join hands with us.

"Our plea of reconsideration is made as a matter of engineering policy and in the cause of a mutually broad and universal specification, which you, of course, realize has been the desire of all parties interested in this

matter for a number of years, and we most respectfully urge that your Association adopt the Overhead Crossing Specification exactly as written.

"We would further suggest that after your Association has adopted this specification as written, that it at once make a recommendation to the Joint Committee covering the changes it desires, in order that the Joint Committee may take them up promptly, having them discussed and worked out by the various representatives of the interests concerned, and worked into the specification at the first opportunity for revision which presents itself.

"The Joint Committee believes that this action on the part of your Association will be a healthy one, and as all the representative parties formulating the specification will have formally adopted the same, each Association, or each individual engineer, will then be in a position to criticize the specification in detail, and the Joint Committee, which is a standing one, will be in a position to take care of such criticisms formally and effectively, and the results of the use of the specification in the field will thus become known to the Joint Committee, and all desirable changes can be made from time to time, so that eventually we should have a specification which will be as perfect as a specification can be, and having started with this one as a sound base, each year's changes can be worked out from the needs of the field engineers discovering weaknesses in the work as it stands to-day, which method we believe to be rational, and quite the best one from the standpoint of all construction engineers or Associations affected by this specification."

The Secretary:—"19. Clearing. The space around the poles, or towers, shall be kept free from inflammable material, underbrush and grass.

"20. Signs. In the case of railroad crossings, if required by the railroad company, warning signs of an approved design shall be placed on all poles and towers located on the railroad company's right-of-way.

"21. Grounding. For voltages over 5,000 volts, wooden crossarms, if used, shall be provided with a grounded metallic plate on top of the arm, which shall be not less than ⅛ inch in thickness and which shall have a sectional area and conductivity not less than that of the line conductor. Metal pins shall be electrically connected to this ground. Metal poles and metal arms on wooden poles shall be grounded.

"22. The electrical conductivity of the ground conductor shall be adjusted to the short-circuit current capacity of the system and shall be not less than that of a No. 4 B. & S. gage copper wire.

"23. Temperature. In the computation of stresses and clearances, and in erection, provision shall be made for a variation in temperature from —20 degrees Fahrenheit to +120 degrees Fahrenheit. A suitable modification in the temperature requirements shall be made for regions in which the above limits would not fairly represent the extreme range of temperature.

"24. Inspection. If required by contract, all material and workmanship shall be subject to the inspection of the company crossed; provided, that reasonable notice of the intention to make shop inspection shall be given by such company; if such notification is not given, the company crossed shall be furnished with certified reports of shop inspection of material and workmanship made by a properly qualified inspector. De-

fective material shall be rejected, and shall be removed and replaced with suitable material."

Mr. Kittredge:—This is one of the paragraphs in question. On the fourth line it says: "If such notification is not given, the company crossed shall be furnished with certified reports of shop inspection of material and workmanship made by a properly qualified inspector." These words do not appear in the report of the Joint Committee, and for the reasons stated I move the adoption of paragraph 24 of the Joint Committee report.

(The motion was carried.)

The Secretary:—"25. On the completion of the work, all falsework, plant and rubbish, incident to the construction, shall be removed promptly and the site left unobstructed and clean.

"26. Drawings. If required, by contract, ... (.....) complete sets of general and detail drawings shall be furnished for approval, before any construction is commenced.

"27. The conductors shall be considered as uniformly loaded throughout their length, with a load equal to the resultant of the dead load plus the weight of a layer of ice ½ inch in thickness, and a wind pressure of 8 lbs. per square foot on the ice-covered diameter, at a temperature of 0 degrees Fahrenheit."

Mr. A. F. Robinson (Santa Fe):—It seems to me the provision for load is hardly sufficient; when ice gathers on wires it seldom forms in a circle, it is oblong and hangs to one side of the wire. That would vitiate the use of a wind pressure of 8 lbs. per square foot, because it is striking more nearly on a plane surface than it would if blowing against the cylinder. It also seems to me it would be better if we could arrive at a uniform load per linear foot, without respect to the size of the wire, size of the supporting cable or anything of that sort. It is a matter of very small moment when you work it out. If you take a 1½-inch wire it means about 1.4 lbs. per linear foot, and it seems to me we could cut nearly all of that out and put a provision in that the wires shall be figured for 10, 15 or 20 lbs. per linear foot, and not say anything about the ice or anything of that sort.

I would offer that as a suggestion for the consideration of the Committee in future revisions of the specification.

The Secretary:—"28. The weight of ice shall be assumed as 57 lbs. per cubic foot (0.033 lbs. per cubic inch).

"29. Insulators, pins and conductor attachments shall be designed to withstand, with the designated factor of safety, the tension in the conductors under the maximum loading, assuming the conductor to be broken on one side of the structure."

Mr. Kittredge:—This is another paragraph that differs from the Joint Committee report, and I move the adoption of paragraph 29, of the Joint Committee report.

(The motion was carried.)

The Secretary:—"30. The pole, or towers, shall be designed to withstand, with the designated factor of safety, the combined stresses from their own weight, the wind pressure on the pole, or tower, and the above wire loading on the crossing span and the next adjoining span on each side. The wind pressure on the poles, or towers, shall be assumed at 13 lbs. per square foot on the projected area of solid or closed structures, and on 1½ times the projected area of lattice structures."

Mr. Ambrose:—In designing your towers, should you not assume one span broken?

The President:—Section 31 takes care of that.

The Secretary:—"31. The poles, or towers, shall also be designed to withstand the most unfavorable condition of the loads specified in paragraph 30, combined with the unbalanced tension of

Two broken wires for poles, or towers, carrying 5 wires or less.

Three broken wires for poles, or towers, carrying 6 to 10 wires.

Four broken wires for poles, or towers, carrying 11 or more wires."

Mr. Kittredge:—Mr. Chairman, this paragraph contains the words, "The most unfavorable condition," which the paragraph of the Joint Committee does not contain. For the reasons already stated I move the adoption of paragraph 31 of the Joint Committee.

Mr. E. B. Katte (New York Central & Hudson River):—I believe in co-operation and in standards, but not in the adoption of a standard unless it is something that is as good as we can make it. This Committee has had a little longer to consider the specifications than the so-called Joint Committee, and at the largest meeting that your Committee on Electricity ever held, it was agreed to make the modifications as printed in the report. I believe that it has been generally admitted by all of the other committees that the changes are good and that they should be made. I have been told that the other committees would consider these modifications and in all probability would accept some, if not all of them, at their next meetings. During the months following these meetings, if you do not adopt the revised specifications we will be lagging behind the other associations. Our specifications will contain thirteen clauses which are improper or at least ambiguous. On the other hand, if we adopt to-day the specifications as modified and printed in your Bulletin, we will be six months in advance. Next fall the other associations will, perhaps, adopt the specifications that are before you to-day; then we will have co-operated in obtaining a joint standard specification and one that does not contain thirteen objectionable clauses.

Mr. R. D. Coombs:—I am compelled to disagree with Mr. Katte, because the main argument for warning this Association not to make changes is to obtain a uniform national standard, and the engineering differences are so slight that personally I do not believe that construction will be impaired during that six months.

Mr. Katte:—This Association has already adopted one change, namely, clause 18. The specifications will not be uniform now. As long as you

have made one change, why not make all the other admittedly desirable changes?

Mr. L. C. Fritch:—There is something to be said on both sides of this question. If we were independent and could say, "We will adopt our own specifications," the chances are the other associations would throw them out, and at about 90 per cent. of the crossings we would have to take whatever they would give us, and for the sake of uniformity, I believe that half a loaf is better than none at all; so I think we ought to adopt these specifications, with the exception of clause 18.

(The question was called for and, on vote, duly carried.)

The Secretary:—"32. Crossarms shall be designed to withstand the loading specified in paragraph 30, combined with the unbalanced tension of the wire, which, when broken, produces the highest fiber stress in the arm."

Mr. Kittredge:—This paragraph differs from the Joint Committee report, in that it uses the words, "which, when broken, produces the highest fiber stress in the arm." For the reasons already stated, I move the adoption of paragraph 32, shown on page 522 of the joint report.

(The motion was carried.)

The Secretary:—"33. The poles, or towers, may be permitted a reasonable deflection under the specified loading, provided that such deflection does not reduce the clearances specified in paragraph No. 10 more than 25 per cent. or produce stresses in excess of those specified in paragraphs Nos. 65 to 69.

"34. The ultimate unit stress divided by the allowable stress shall be not less than the following:

Wires and cables	2
Pins	2
Insulators, conductor attachments, guys	3
Wooden poles and crossarms	6
Structural steel	3
Reinforced concrete poles and crossarms	4
Foundations	2

"NOTE.—The treating of wooden poles and crossarms is recommended. The treatment of wooden poles and crossarms should be by thorough impregnation with preservative by either closed or open-tank process. For poles, except in the case of yellow pine, the treatment need not extend higher than a point 2 feet above the ground line."

Mr. Kittredge:—This last paragraph contains a difference in the first sentence of the note. The joint paragraph reads, "The ultimate unit stress divided by the allowable unit stress shall be not less than the following, etc." For the reasons already stated, I move the adoption of the paragraph shown on pages 522 and 523.

(The motion was carried.)

The Secretary:—"35. Insulators. Insulators for line voltages of less than 9,000 shall not flash over at four times the normal working voltage,

under a precipitation of water of 1/5 of an inch per minute, at an inclination of 45 degrees to the axis of the insulator.

"36. Each separate part of a built-up insulator, for line voltages over 9,000, shall be subjected to the dry flash-over test of that part for five consecutive minutes.

"37. Each assembled and cemented insulator shall be subjected to its dry flash-over test for five consecutive minutes.

"The dry flash-over test shall be not less than:

Line Voltage.	Test Voltage.
Exceeding 9,000, but not exceeding 14,000	65,000
Exceeding 14,000, but not exceeding 27,000	100,000
Exceeding 27,000, but not exceeding 35,000	125,000
Exceeding 35,000, but not exceeding 47,000	150,000
Exceeding 47,000, but not exceeding 60,000	180,000
Exceeding 60,000	3 times line voltage

"Each insulator shall further be so designed that, with excessive potential, failure will first occur by flash-over and not by puncture.

"38. Each assembled insulator shall be subjected to a wet flash-over test, under a precipitation of water of 1/5 inch per minute, at an inclination of 45 degrees to the axis of the insulator.

"The wet flash-over test shall be not less than:

Line Voltage.	Test Voltage.
Exceeding 9,000, but not exceeding 14,000	40,000
Exceeding 14,000, but not exceeding 27,000	60,000
Exceeding 27,000, but not exceeding 35,000	80,000
Exceeding 35,000, but not exceeding 47,000	100,000
Exceeding 47,000, but not exceeding 60,000	120,000
Exceeding 60,000	twice the line voltage

"39. Test voltages above 35,000 volts shall be determined by the A. I. E. E. Standard Spark-Gap Method.

"40. Test voltages below 35,000 volts shall be determined by transformer ratio.

"41. Conductors. The conductors shall be of copper, aluminum, or other noncorrodible material, except that in exceptionally long spans, where the required mechanical strength cannot be obtained with the above materials, galvanized or copper-covered steel strand may be used.

"42. For voltages not exceeding 750 volts, solid or stranded conductors may be used up to and including 4/0 in size; above 4/0 in size, stranded conductors shall be used. For voltages exceeding 750 volts, and not exceeding 5,000 volts, solid or stranded conductors may be used up to and including 2/0 in size; above 2/0 in size, conductors shall be stranded. For voltages exceeding 5,000 volts, all conductors shall be stranded. Aluminum conductors for all voltages and sizes shall be stranded.

The minimum size of conductors shall be as follows:

No. 6 B. & S. gage copper for voltages not exceeding 5,000 volts.

No. 4 B. & S. gage copper for voltages exceeding 5,000 volts.

No. 1 B. & S. gage aluminum for all voltages.

"43. Insulators. Insulators shall be of porcelain for voltages exceeding 5,000 volts.

"44. Strain insulators for guys shall have an ultimate strength of not less than twice that of the guy in which placed. Strain insulators shall be so constructed that the guy wires holding the insulator in position will interlock in case of the failure of the insulator.

"Strain insulators for guys shall not flash over at four times the maximum line voltage, under a precipitation of water of 1/5 inch per minute, at an inclination of 45 degrees to the axis of the insulator.

"45. Pins. For voltages of 5,000 and over, insulator pins shall be steel, wrought iron, malleable iron, or other approved metal or alloy, and shall be galvanized, or otherwise protected from corrosion. Pins shall be locked with cotter, nut, or other device, to prevent raising out of the socket or hole in the crossarm."

Mr. Kittredge:—This paragraph varies from that of the joint report in that the last sentence of this paragraph does not appear in the joint report, "Pins shall be locked with cotter," etc. For the reasons already stated, I move that paragraph 45, on page 523, be adopted.

(The motion was carried.)

The Secretary:—"46. Guys. Guys shall be galvanized or copper-covered stranded steel cable, not less than 5/16 inch in diameter, or galvanized rolled rods of equivalent tensile strength.

"47. Guys to the ground shall connect to a galvanized anchor rod, extending at least 1 foot above the ground level.

"48. The detail of the anchorage shall be definitely shown upon the plans.

"49. Wooden Poles. Wooden poles shall be of selected timber of approved species, peeled, free from defects which would decrease their strength or durability, not less than 7 inches minimum diameter at the top, and meeting the requirements as specified in paragraphs 17, 30, 31 and 34."

Mr. Kittredge:—Mr. Chairman, this varies from the joint report paragraph in that the joint report paragraph omits the words, "of approved species." For the reasons already given, I move the adoption of paragraph 49, on page 523.

(The motion was carried.)

The Secretary:—"50. Concrete. All concrete and concrete material shall be in accordance with the requirements of the Report of the Joint Committee on Concrete and Reinforced Concrete.

"51. Structural steel shall be open-hearth, in accordance with the Manufacturers' Standard Specifications."

Mr. Kittredge:—This paragraph differs from the Joint Committee paragraph in that the word "open-hearth" is omitted in the joint specification. For the reasons already stated, I move the adoption of paragraph 51, page 523.

Mr. Earl Stimson (Baltimore & Ohio):—It would be interesting to

me to know why the Committee prepared these specifications, knowing the Joint Committee specifications were already in existence, and recommending them for adoption, and even going so far as to state that their own specifications were more satisfactory, and now be willing to modify them to conform to the joint specifications in every respect.

Mr. Kittredge:—When these specifications were adopted by your Committee and sent for printing in the Bulletin, we were led to believe by the Joint Committee that if they varied in any particular it would be just as if we had thrown over their whole specifications. Afterward, when we met several members of the Joint Committee and explained to them our immovable position in regard to clause 18, they said they would undertake to modify their clause 18 to meet ours, if we would modify the others to meet theirs. That is the sole and only reason we have for recommending as we do.

(The motion was carried.)

The Secretary:—"52. The design and workmanship shall be strictly in accordance with first-class practice.

"53. The form of the frame shall be such that the stresses may be computed with reasonable accuracy, or the strength shall be determined by actual test.

"54. The sections used shall permit inspection, cleaning and painting, and shall be free from pockets in which water or dirt can collect.

"55. The length of a main compression member shall not exceed 150 times the least radius of gyration. The length of a secondary compression member shall not exceed 180 times its least radius of gyration."

Mr. Kittredge:—This varies in that the "150" of our report is "180" of the Joint Committee report and the 180 of our report, on the last line, is 220 in the joint report. For the reasons already stated, I move the adoption of paragraph 55, page 523.

(The motion was carried.)

The Secretary:—"56. The minimum thickness of metal in galvanized structures shall be ¼ inch for main members, and ⅛ inch for secondary members. The minimum thickness of painted material shall be ¼ inch.

"57. All structural steel shall be thoroughly cleaned at the shop and be galvanized, or given one coat of approved paint.

"58. Painted Material. All contact surfaces shall be given one coat of paint before assembling.

"All painted structural steel shall be given two field coats of an approved paint.

"The surface of the metal shall be thoroughly cleaned of all dirt, grease, scale, etc., before painting, and no painting shall be done in freezing or rainy weather.

"59. Galvanized Material. Galvanized material shall be in accordance with the Specifications for Galvanizing Iron and Steel (Appendix).

"Bolt holes in galvanized material shall be made before galvanizing.

"60. The foundations for steel poles and towers shall be designed to prevent overturning.

"The weight of concrete shall be assumed as 140 lbs. per cubic foot. In good ground, the weight of 'earth' shall be assumed as 100 lbs. per cubic foot. In swampy ground, special measures shall be taken to prevent uplift or depression."

Mr. Kittredge:—This varies from the Joint Committee report in that the latter has a bracketed clause which says, "Calculated at 30 degrees from the vertical." For the reasons already stated, I move the adoption of paragraph 60, page 523.

(The motion was carried.)

The Secretary:—"61. The top of the concrete foundation, or casing, shall be not less than 12 inches above the surface of the ground or extreme high water."

Mr. Kittredge:—This varies from the Joint Committee report in that the Joint Committee report says, "The top of the concrete foundation, or casing, shall be not less than 6 inches above surface of the ground, nor less than 1 foot above extreme high water." For the reasons already stated, I move the adoption of paragraph 61, on page 523.

(The motion was carried.)

The Secretary:—"62. When located in swampy ground, wooden crossing and next adjoining poles shall be set in barrels of broken stone or gravel, or in broken stone or timber footings.

"63. When located in the sides of banks, or when subject to washouts, foundations shall be given additional depth, or be protected by cribbing or riprap.

"64. All foundations and pole settings shall be tamped in 6-inch layers, while back filling.

"Working Unit Stresses.—Obtained by dividing the ultimate breaking strength by the factors of safety given in paragraph 34.

		Lbs. per sq. in.
"65.	Structural Steel. Tension (net section)	18,000
	Shear	14,000
	Compression	$18{,}000-60\frac{l}{r}$
"66.	Rivets, Pins. Shear	10,000
	Bearing	20,000
	Bending	20,000
"67.	Bolts. Shear	8,500
	Bearing	17,000
	Bending	17,000
"68.	Wires and Cables. Copper, hard-drawn, solid, B. & S. gage, 4/0, 3/0, 2/0	25,000
	Copper, hard-drawn, solid, B. & S. gage, 1/0	27,500
	Copper, hard-drawn, solid, B. & S. gage, No. 1	28,500
	Copper, hard-drawn, solid, B. & S. gage, Nos. 2, 4, 6	30,000
	Copper, soft-drawn, solid, B. & S	17,000
	Copper, hard-drawn, stranded, B. & S	30,000

Copper, soft-drawn, stranded, B. & S.	17,000
Aluminum, hard-drawn, stranded, B. & S. gage, under 4/o	12,000
Aluminum, hard-drawn, stranded, B. & S. gage, 4/o and over	11,500

"69. Untreated Timber.

	Bending.	Compression.
Eastern white cedar	600 lbs. per sq. in.	$600\left(1-\frac{L}{60D}\right)$
Chestnut	850 lbs. per sq. in.	850 "
Washington cedar	850 lbs. per sq. in.	850 "
Idaho cedar	850 lbs. per sq. in.	850 "
Port Orford cedar	1150 lbs. per sq. in.	1150 "
Long-leaf yellow pine	1100 lbs. per sq. in.	1100 "
Short-leaf yellow pine	950 lbs. per sq. in.	950 "
Douglas fir	1000 lbs. per sq. in.	1000 "
White oak	950 lbs. per sq. in.	950 "
Red Cedar	700 lbs. per sq. in.	700 "
Bald cypress (heartw'd)	800 lbs. per sq. in.	800 "
Redwood	850 lbs. per sq. in.	850 "
Catalpa	500 lbs. per sq. in.	500 "
Juniper	550 lbs. per sq. in.	550 "

L = Length in inches.

D = Least side, or diameter, in inches.

"SPECIFICATIONS FOR GALVANIZING FOR IRON OR STEEL.

"These specifications give in detail the test to be applied to galvanized material. All specimens shall be capable of withstanding these tests.

"(A) Coating. The galvanizing shall consist of a continuous coating of pure zinc of uniform thickness, and so applied that it adheres firmly to the surface of the iron or steel. The finished product shall be smooth.

"(B) Cleaning. The samples shall be cleaned before testing, first with carbona, benzine or turpentine and cotton waste (not with a brush), and then thoroughly rinsed in clean water and wiped dry with clean cotton waste.

"The sample shall be clean and dry before each immersion in the solution.

"(C) Solution. The standard solution of copper sulphate shall consist of commercial copper sulphate crystals dissolved in cold water, about in the proportion of 36 parts, by weight, of crystals to 100 parts, by weight, of water. The solution shall be neutralized by the addition of an excess of chemically pure cupric oxide (Cu O). The presence of an excess of cupric oxide will be shown by the sediment of this reagent at the bottom of the containing vessel.

"The neutralized solution shall be filtered before using by passing through filter paper. The filtered solution shall have a specific gravity of 1.186 at 65 degrees Fahrenheit (reading the scale at the level of the solu-

tion) at the beginning of each test. In case the filtered solution is high in specific gravity, clean water shall be added to reduce the specific gravity at 1.186 at 65 degrees Fahrenheit. In case the filtered solution is low in specific gravity, filtered solution of a higher specific gravity shall be added to make the specific gravity 1.186 at 65 degrees Fahrenheit.

"As soon as the stronger solution is taken from the vessel containing the unfiltered neutralized stock solution, additional crystals and water must be added to the stock solution. An excess of cupric oxide shall always be kept in the unfiltered stock solution.

"(D) Quantity of Solution. Wire samples shall be tested in a glass jar of at least 2 in. inside diameter. The jar without the wire samples shall be filled with standard solution to a depth of at least 4 in. Hardware samples shall be tested in a glass or earthenware jar containing at least ½ pint of standard solution for each hardware sample.

"Solution shall not be used for more than one series of four immersions.

"(E) Samples. Not more than seven wires shall be simultaneously immersed, and not more than one sample of galvanized material other than wire shall be immersed in the specified quantity of solution.

"The samples shall not be grouped or twisted together, but shall be well separated so as to permit the action of the solution to be uniform upon all immersed portions of the samples.

"(F) Test. Clean and dry samples shall be immersed in the required quantity of standard solution in accordance with the following cycle of immersions.

"The temperature of the solution shall be maintained between 62 degrees and 68 degrees Fahrenheit at all times during the following test:

"(1) Immerse for one minute, wash and wipe dry.

"(2) Immerse for one minute, wash and wipe dry.

"(3) Immerse for one minute, wash and wipe dry.

"(4) Immerse for one minute, wash and wipe dry.

"After each immersion the samples shall be immediately washed in clean water having a temperature between 62 degrees and 68 degrees Fahrenheit, and wiped dry with cotton waste.

"In the case of No. 14 galvanized iron or steel wire, the time of the fourth immersion shall be reduced to ½ minute.

"(G) Rejection. If after the test described in section (F) there should be a bright metallic copper deposit upon the samples, the lot represented by the sample shall be rejected.

"Copper deposits on zinc or within 1 in. of the cut end shall not be considered causes for rejection.

"In the case of a failure of only one wire in a group of seven wires immersed together, or if there is a reasonable doubt as to the copper deposit, two check tests shall be made on these seven wires and the lot reported in accordance with the majority of the sets of tests.

"NOTE.—The equipment necessary for the tests herein outlined is as follows:

"Filter paper.

"Commercial copper sulphate crystals.

"Chemically pure cupric oxide (Cu O).

"Running water.

"Warm water or ice, as per needs.

"Carbona, benzine or turpentine.

"Glass jars at least 2 in. inside diameter by at least 4½ in. high.

"Glass or earthenware jars for hardware samples.

"Vessel for washing samples.

"Tray for holding jars of stock solution.

"Jars, bottles and porcelain basket for stock solution.

"Cotton waste.

"Hydrometer cylinder 3 in. diameter by 15 in. high.

"Thermometer with large Fahrenheit scale correct at 62 and 68 degrees.

"Hydrometer correct at 1.186 at 65 degrees Fahrenheit."

Mr. Kittredge:—I move the adoption of specifications for overhead crossings, as amended.

(The motion was carried.)

Mr. Kittredge:—The recommendation of the Committee is the continuation of work already outlined.

Mr. A. F. Robinson:—I may be a little bit late, but I want to call attention to two or three items in these specifications we have adopted that are not consistent with our specifications for structural material, and to suggest that a small committee of one or two persons be appointed to confer with the Committee on Electricity, suggesting these minor changes, which they wish put up to the Joint Committee later on for adoption. These changes will make the specifications consistent with our printed specifications, and with ordinary working conditions, and I think will be a decided improvement. I am not offering this with any idea of objecting to the specifications as a whole, but simply to make them consistent all the way through. I think it could be handled very easily in this manner, so that the Committee on Electricity can get the matter into shape for presentation to the Joint Committee.

Mr. F. J. Bachelder (Baltimore & Ohio):—I would like to ask if the manufacturer's standard specifications mentioned in paragraph 51 are the same as the specifications of this Association.

Mr. Robinson:—That was one of the items I had in mind in speaking.

The President:—Mr. Robinson, will you write a letter to the Chairman of the Committee?

Mr. Robinson:—Yes, I will, and cover all the features I have in mind.

Mr. Kittredge:—The Committee would not only gladly accept such a letter, but would gladly accept the names of any individuals whom Mr.

Robinson might suggest, who would prove valuable members of the Committee. We would be glad to have two or three more good members and would welcome more such men as Mr. Robinson refers to.

Mr. Ambrose:—Is it understood that the Committee will take up these higher voltages at once? We have several crossings now in existence carrying 110,000 volts and would be glad to have some recommendation.

Mr. Kittredge:—I would suggest that such a letter be addressed to the Board of Direction, so that it will come before the Committee in the regular formal way.

The President:—The Committee is dismissed with the thanks of the Association. There has been an immense amount of work done in this connection.

DISCUSSION ON RAIL.

(For Report, see pp. 559-562.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON RAIL.

CHAS. S. CHURCHILL.	GEORGE W. KITTREDGE.	JOHN G. SULLIVAN.
R. D. COOMBS.	C. E. LINDSAY.	G. H. TINKER.
W. C. CUSHING.	W. L. SEDDON.	ROBERT TRIMBLE.
L. C. FRITCH.	W. F. STEFFENS.	WALTER LORING WEBB.
JAMES E. HOWARD.		

The President:—The next report is that of the Committee on Rail, Mr. Chas. S. Churchill, Chairman. The Chairman is requested to make the preliminary statement.

Mr. Chas. S. Churchill (Norfolk & Western):—The report of the Rail Committee begins at the top of page 560. We have there, in the first place, the answer to our instruction No. 3, "Continue the investigation of breakage and failure of rails." This being a study of failed rails up to October 31, 1910, with conclusions.

"(1) Study of these general statistics does not furnish accurate and specific information so as to determine the value of different sections of rail, because (a) The conditions of traffic are different; (b) the conditions of roadbed are different; (c) the conditions of ingot making and rolling practice are so different that the quality of the material varies widely, and, at the present time, this difference in quality of the material eliminates differences in section; nevertheless, when the time comes that the difference in quality of material will be less, the influence of the section will be more apparent, for there is no doubt that one section is stiffer and stronger than another according to the distribution of the material. Inasmuch as we are endeavoring to eliminate the differences in quality of material and bring it to a high state of perfection, we should not, in the meantime, lose sight of the desirable features of the rail section, but keep them constantly in mind, so that when we arrive at a good quality of metal, we will also have a desirable rail section.

"(2) A study of these general statistics tends to disclose unusual results, and were it not for their compilation, we would not have much information relative to the difference between Bessemer and Open-Hearth steel and concerning the various alloys.

"(3) The general statistics are also important, in showing a relation between broken rails and failure of head, web and base.

"(4) Their tabulation discloses the difference between Steel Companies when the sections and chemical composition are practically the same.

"The report by Mr. Wickhorst covers an investigation made at the South Works of the Illinois Steel Company, to throw light on the relationship of the size of ingots of Bessemer Rail steel to the segregation of the metalloids, locations of pipes and blow holes, and the properties of the rails. This investigation showed that under the conditions of the tests, the carbon, phosphorus and sulphur collected or segregated toward the interior and upper part of the ingot and that, in a general way, such segregation increased as the size of the ingot increased. The manganese also segregated some, but to a much smaller extent, while the silicon showed little or no tendency to segregate.

"The elements which segregated as described also showed a lowering in the top part of the ingot, below the average composition of the steel and this lowering extended downward along the sides of the ingot. The 'negative' segregation increased in general as the size of the ingot increased and also extended down further along the sides of the ingot. There was also a region of negative segregation in the interior and lower part of the ingot, but the lowering of the elements was not as great in this region.

"This investigation also indicated that the material was distributed in the rail bar about the same, relatively, as it was in the ingot from which the rail bar had been rolled.

"(D) Tests of Rail Steel Ingots and Derivative Shapes Made at Watertown Arsenal, being a Review by M. H. Wickhorst of the Report Published by the Watertown Arsenal (Bulletin No. 139, September, 1911.)

"This report covers a digest and analysis of the Government investigation at the Watertown Arsenal of rail steel ingots and derivative shapes as embodied in the Report of Tests of Metals, etc., made at the Watertown Arsenal for the year 1909.

"The work indicated that the interior cavities of an ingot cooled directly after pouring are about the same or slightly less than in a similar ingot placed in the soaking pit and then cooled. This same result was also indicated as true of blooms made from such ingots.

"It was shown that almost the full tensile strength and ductility of the metal of the lower part of the ingot were obtained rolling to about one-tenth of the original cross-section, but with the metal of the upper part of the ingot it was necessary to reduce the cross-section to one-twenty-fifth or less of the original amount.

"A great many etchings were made and it was shown that the structure of the cross-section as developed by etching varies from the top to the bottom of the ingot and that each structure finds its counterpart in succeeding shapes and at about the same proportionate distance from the top end. It was also shown that the structure was considerably altered by changing the position in which the ingot was allowed to cool, as for instance allowing it to cool on its side after stripping.

"(E) Influence of Rolling Temperature on the Properties of Bessemer Rails, by M. H. Wickhorst, November, 1911.

"This report covers an investigation made at the works of the Car-

negie Steel Company to determine the influence of the temperature of rolling on the properties of Bessemer Rails. This work indicated that the ductility and deflection in the drop test were influenced little, if any, by the rolling temperature. The number of blows that it took to break the rails in the drop test was uninfluenced by the temperature of rolling. The yield point and tensile strength in the tension tests were influenced little, if any. The elongation in the tension test decreased some as the temperature increased. The influence of temperature showed most prominently in the tension test, in the reduction of area, which decreased as the temperature of rolling increased. The size of the grain, as shown by the microscope, increased as the temperature increased.

"In this report it is also pointed out that the ductility in the drop test with the head of the rail in tension more nearly indicates the ductility of the interior metal as measured in the tension test, than does the ductility in the drop test with the base of the rail in tension, which is usual in inspection work.

"Each report mentioned above gives a short summary of the matter contained in it, but the main principles that seem to have been brought out by the year's work are set forth in the brief reviews above."

That shows the work that this Committee has done during the year.

I will refer now to the requirement, "Present recommendations on standard rail sections." The Committee reports progress on this. We think that the information that is coming, not yet tabulated, on rail failures for the period ending October 31, 1911, together with information that has come in since that date, is going to be of such assistance that this Committee can make very rapid progress upon this question. Therefore the Committee reports progress only on this instruction.

We have carried investigation of the failure of rails up to October 31, 1910. Similar statements and conclusions will be prepared and published in the course of probably two months on the tabulation of rail failures for the period ending October 31, 1911.

The Committee was further instructed to report on the results obtained from the use of Open-Hearth and Special Alloy Steel Rails, and the chemical composition of such rails.

Bulletin No. 137, referred to above, containing the report of the rail failure statistics, also gives all the information that the Committee has in regard to Open-Hearth and Special Alloy Steel Rails.

I have simply referred to these few items so that the members of the Association will catch quickly the salient features of the report.

With these remarks of the work in general, I wish now to refer to page 562 of Bulletin 143, and take up the matter beginning with section 1:

"(1) The first item of work for the Rail Committee according to the instructions for 1911, was to recommend changes in the specifications for steel rails.

"Considerable work has been done during the past year in the preparation of specifications, and the specifications submitted herewith are rec-

ommended by your Committee. Some paragraphs, such as Nos. 5, 6, 14 and 15, are not to be considered as final, it being thought that the Committee did not have sufficient information in its possession to make these sections in the specifications mandatory.

One of the sections in question, No. 14, refers to the ductility test.

The requirements, in the specifications, for ductility are somewhat lower than some members of your Committee think desirable, and it is hoped that sufficient information will be obtained during the coming year to enable the Committee to make some revision in these respects.

"Paragraph No. 15, referring to deflections as a method of classifying rails, is also tentative. It is the intention when sufficient data is at hand to prescribe maximum and minimum limits for deflections under the drop test."

The Committee, therefore, asks that the specifications we recommend be now considered and that they be adopted as good practice, and to that end I would suggest that we take up the specifications so that they may be discussed and passed upon by paragraphs.

The President:—With the consent of the Association, the Secretary will read the specifications paragraph by paragraph and will pass from one to the other without formal action, unless some motion is made.

The Secretary:—"1. Access to Works.—Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while the contract is being executed, and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the rails have been made in accordance with the terms of the specifications.

"2. Place for Tests.—All tests and inspections shall be made at the place of manufacture, prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the mill.

"3. Material.—The material shall be steel made by the Bessemer or Open-Hearth process provided by the contract.

"4. Chemical Composition.—The chemical composition of the steel from which the rails are rolled, determined as prescribed in Section 7, shall be within the limits set forth in the table. (See page 565.)"

The President:—We have with us to-day at our invitation Mr. James E. Howard, of the Bureau of Standards, and if he is present in the room I would be glad to have him make some remarks. You all know Mr. Howard; he has been present at our meetings before.

Mr. James E. Howard (Bureau of Standards):—Mr. President and Gentlemen: In regard to the general subject of rail, it has been my privilege to make a number of tests on different occasions, and I feel very gratified at this opportunity of making a few remarks before you. The work your Committee has in hand is advancing the subject very materially and so far I think it has proceeded in a highly satisfactory manner.

It seems, however, that some features connected with the rail situation ought to be considered which are perhaps a little out of the usual order, in addition to what we have heretofore directed our attention to.

In regard to matters of test—specifications—I never feel like tying

myself down very closely to specifications. They are necessary, but not all that is needed.

I will refer to a few of the features which have just been suggested by reading paragraphs in your specifications. As to this question of ductility and the deflections in the drop tests, when we come to analyze the case, it seems that the drop test means simply this—that it gives us an indication of well-worked metal. I do not know that it does very much more. If we have the composition of the steel and it is cast in an ingot and reduced thirty or forty times, we have good evidence when it reaches the form of a rail that it is well-worked steel. I do not know that we could secure better evidence that it has been well-worked than the fact that it has become a rail, so the drop test, in that respect, merely shows we have secured what we know we have.

In regard to the deflection, what does that mean further than that one ordinate of a stress-strain curve has been reached. If we make a tension test of steel we get its elastic limit, and as it is stretched at different intervals beyond also the total extension, and the contraction area. Now, we are not content usually with just one ordinate of that character, and I would request, for consideration, whether the drop test carries with it quite enough information in this respect. We wish to know something about the elastic limit of the material, and we do not know what that is from the results of the drop test.

Then it goes back to the question of what elastic limit is needed in steel rails. It comes to the definition or recognition of what fiber stresses you have in rails. I do not know what fiber stresses are involved in rails in the track. Some of the gentlemen present may be in possession of definite information, but it is doubtful. Earlier tests which I had the pleasure of conducting showed that the fiber stress per ton on the wheels varied with different types of engines and different wheels of the same engine, so that I feel that in general the specifications and tests had not yet touched upon some of the vital points.

Then, again, in regard to the extension due to the drop test, we are stretching the metal in the most favorable direction. If we had the same ductility in the crosswise direction that we have longitudinally, I do not think there would be so many base fractures. The crescent-shaped fractures are due to a want of structural soundness, which is very evident when the bases are bent in a crosswise direction, but these defects are not apparent when we stretch the material in a lengthwise direction.

I hope I am not criticising too many features at this time, but it seems that these are the things which we ought to consider in addition to those features which now are covered by specifications.

Concerning the question of chemical analysis, the few observations that I have made have shown that the composition of the rail in its cross-section may vary considerably. I will not say it generally varies so much as witnessed in a recent case, but in a recent case the carbon at the outer portions was 0.44 per cent. to 0.45 per cent., while at the center of the head it was as high as 0.77 per cent. That variation in composition is quite wide,

but do you find in the test ingot very much clew to what actually reaches you in the rails? Should not the rails themselves now and then be carefully analyzed for the purpose of determining whether segregated parts of the ingot were used or whether the outer portions of the rails are not in a measure decarbonized? There are reasons for thinking there is need for such procedure.

Doubtless there are other features of importance which do not at this time occur to me, but I should be very happy to answer any questions that I may be able to answer, if anyone present would kindly make the inquiries; however, these are the salient features which to me seem desirable to consider, and their consideration may aid in securing a better material.

The President:—Have you any criticism to make on this particular paragraph that we have just read in reference to the chemical composition proposed for these specifications? We would be glad to know what you think in regard to that.

Mr. Howard:—The chemical composition carries with it the idea of certain physical properties. First, to consider what the physical property should be and then work back from that to the chemical composition. We have in that case to go back to the fiber stresses which are involved and until they are defined we cannot reach a definite conclusion; that is, considering the rail as a beam subjected to bending stresses. As to the wheel pressures, cold-rolling on the running surface of the head, that is still another question. In general, low-carbon steel responds quickly to the cold-rolling of the wheel, and we do not have a very high stress before the elastic limit is reached. Higher carbon steel than a mild one is certainly necessary. But there is danger in going too far, getting too high a carbon, introducing great brittleness, therefore, I am inclined to favor a medium carbon; doubtless the zone of safety lies around 0.65 per cent. to 0.70 per cent., or a little outside of those limits.

The President:—For open-hearth, Mr. Howard?

Mr. Howard:—I am not prepared to make a distinction between the two kinds of steel at the present time.

This feature of ductility is one to be considered and we do know this —that when a material is subjected to repeated alternate stresses it may be ruptured without the display of any ductility whatever. If we have a very low carbon steel, although one of great ductility at the outset, when this is subjected to a comparatively low fiber stress, in alternate directions, we very quickly reach a brittle fracture. That metal will fail without any display of ductility, and the hardest steel can hardly do less. It is necessary to start with considerable stiffness or strength in the material to resist bending stresses. The ductility which you find in the drop test is inherent to the new material and not to that which has been repeatedly strained. It is not necessary that the overstraining force reaches the elastic limit of the material, to bring about that final state of brittleness. Too soft a metal is undesirable to use. If the metal is a strong one, a higher stress can be endured repeatedly without impairing the final

ductility or such ductility as the metal may incidentally be called upon to develop. That leads to the use of rather high carbons and to be conservative, I think around 0.55 to 0.70 is a fair limit.

The dangers of higher carbon, as I see them, are somewhat along these lines: With high carbon steel, and high wheel pressures, we reach an unsatisfactory internal condition. To follow the action of the high wheel pressures, they move the metal on the surface of the head and induce internal strains of compression. These internal strains may be of considerable magnitude, and when they exist there must be a tensile component in the steel below it. In that case we have below the running surface of the head, metal which is put into tension, and if structurally unsound there is an opportunity present for an incipient fracture to develop. To show that the stresses from a disturbing cause like those under consideration are considerable, I would mention an example, referring to a steel forging, one which had walls 3½ inches in thickness. The metal of that cylinder was so disturbed by hammering with a hand hammer that the bore was measurably enlarged. The dimensions of this cylinder were 8 inches; bore, 15 inches outside diameter. Hammering the outside surface of the cylinder, the bore was enlarged nearly one-thousandth of an inch. Turning off one-eighth of an inch of metal, on a side, restored the diameter of the bore to its primitive dimension. That showed that the internal strains in a zone only ⅛-inch thick were capable of stretching the balance of 3½ inches and making its effect measurable. It meant several thousand pounds stress per square inch to do that, so that it is possible that the cold-rolled surface of the head of the rail may have in it internal strains amounting to a number of thousand pounds per square inch, and that coupled with that fact we may have a decarbonized exterior, with a hard center, the decarborized exterior responding easily to the rolling of the wheels, the hard interior, through its natural lack of ductility, not responding so well, we have presented ample opportunity, it would seem, for starting a fracture in the hard steel.

These are features which are regarded as important in considering what the composition of the steel should be and would lead to limiting it to the range in carbon which I have mentioned, and to the exercising of care to see that the steel in the finished rail is fairly uniform in its composition from the exterior surface to the center of the head.

Mr. Churchill:—You stated that you did not wish to express yourself as to the chemical analysis as between open-hearth and Bessemer—do you not think that the lowering of the phosphorus we get in the open-hearth is a very valuable item to balance the large amount of carbon in the Bessemer steel? I believe you think that and I want to bring out that point.

Mr. Howard:—I think that is undoubtedly true, but the effect of these metalloids, which is well recognized, and which I quite concur in, justify us in keeping them to the minimum.

Mr. G. H. Tinker (New York, Chicago & St. Louis):—The speci-

fication states that silicon is not to exceed 0.20. I ask if it would not be proper to have also a low limit on the silicon; say that it should not go below 0.13?

Mr. Howard:—In regard to the general chemical problem, I would not like to go too far in expressing an opinion. I would prefer to turn that over to the steel men.

Mr. Robert Trimble (Pennsylvania Lines):—Mr. Howard has talked about the large internal strains which are set up. Take a steel with an ultimate tensile strength of about 150,000 pounds per square inch; how much internal stress can be set up in that steel necessary to cause a fracture?

Mr. Howard:—The internal stresses that can be set up in a steel can easily reach its elastic limit. If the steel had an elastic limit of say from 35,000 to 45,000 pounds per square inch, we could closely approach that stress.

Mr. Trimble:—You could not go over that?

Mr. Howard:—No; then we would get a display of ductility.

Mr. Trimble:—I understood you to say it might go over 100,000 pounds per square inch?

Mr. Howard:—No; I do not think I mentioned that. When the steel is disturbed (overloaded) by cold-working, internal strains are certain to result. When a beam is bent transversely, while the load is sustained, one side will necessarily be in tension, the other in compression, but a beam which is given a permanent bend, so as not to spring back straight again when the load is released, will have internal strains from the inside to the outside, described as follows: First tension, then compression, then the neutral axis, then tension and then compression on the very outside—that is what you will find in a bent beam, one which has been bent beyond its elastic limit. In the case of straightening rails, and it is impractical to straighten them except when cold, then you will get the combination of internal strains just described and in such a state of equilibrium that a few pounds load will be sufficient to remove some of the initial straightening. Such a result cannot be avoided. That is one of the conditions we have to reckon with, and there is no escape from it. Observations show that very little additional stress on a cold straightened rail will put back some of its former deflection, that we cannot escape from, and the intensity of the internal strains may coincide very closely with elastic limit of the material.

Mr. C. E. Lindsay:—I would like to ask Mr. Howard if in his opinion the process of annealing would permit the parts to adjust themselves and relieve internal strain?

Mr. Howard:—Annealing certainly does restore it. Steel responds very readily to annealing temperatures. Internal strains introduced by cold working can also be put in with great facility by heating and quenching. Heat a cylinder to not exceeding 1,000 degrees Fahrenheit, quench with cold water from the bore, and initial compression

of 40,000 pounds per square inch may easily result. These internal strains may be eliminated by annealing. The annealing, to be efficient, has to be carried on at such a temperature that the metal does not have at that time an appreciable elastic limit. Steel appears to have some strength at all temperatures up to fusion, but it is of a viscous nature at the higher temperatures. When those softening viscous temperatures are reached, there is very little or no real elastic limit, and if the steel is then slowly cooled internal strains will be eliminated.

Mr. Churchill:—So far as Mr. Howard's statement refers to No. 4 alone, in behalf of the Committee I would state that the chemistry is the chemistry of the best rails that we have in service to-day, and have had for years. It is not the extreme, one way or the other. In carbon it is the limit prescribed in a number of both manufacturers' and other specifications that have been used recently, and the limits are those within which the manufacturers say they can work, and therefore we want to make especially clear the fact that there is no departure whatsoever in the chemical part of the specifications from what has been regarded for years as good practice.

Mr. L. C. Fritch (Chicago Great Western):—Some manufacturers in the Bessemer process recommend 0.43 to 0.53 as the limit of carbon for 85 to 100-lb. rail. I would like to have the Committee state if they think that lower limit would not be more satisfactory than the limit of 0.45 to 0.55.

Mr. Churchill:—We do not think that the little variation of the two points—two-hundredths in carbon—has any bearing in a lower limit. This is a workable range, 0.45 to 0.55, that the manufacturers have been endeavoring to adhere to; and they are, we think, keeping their rails more within those limits in recent years than they were before. The long series of tests reported last year in the second volume of Proceedings shows how nearly it is practicable to keep a rail within the specified limits as to chemistry. We think, therefore, there is no advantage gained in slightly modifying either the lower limit or the higher limit. If there was anything to be gained, of course, the Committee would be ready to consider it. I would say that this fourth paragraph has been passed upon by the Manufacturers' Committee as well as the Rail Committee and agreed to.

The President:—Any further discussion on No. 4? If not, the Secretary will read No. 5.

The Secretary:—"No. 5. Modification of Carbon for Low Phosphorus. When the material used at any mill is such that the average phosphorus content of the ingot metal used in the Bessemer process is running below 0.08 and in the Open-Hearth process is running below 0.03, and if it seems mutually desirable, the carbon may be increased at the rate of 0.035 for each 0.01 that the phosphorus content of the ingot metal used averages below 0.08 for Bessemer steel, or 0.03 for Open-Hearth steel."

Mr. L. C. Fritch:—Before we pass No. 5, I do not think it is quite clear enough. It says: "When the material used at any mill is such that the average phosphorus content of the ingot metal used in the Bessemer process is runing below 0.08 and in the open-hearth process is running below 0.03, and it seems mutually desirable, the carbon may be increased at the rate of 0.035 for each 0.01 that the phosphorus content is lower"—that means the decrease of the phosphorus. If you want the lower phosphorus, you want the higher carbon. Therefore, I think it should show the decrease of 0.035. Phosphorus content would be clearer.

Mr. Churchill:—No; it is the other way.

Mr. L. C. Fritch:—Where you have decrease in the phosphorus, you can raise the carbon. It does not seem quite clear to me.

Mr. Churchill:—I think if you will reread that carefully it will be clear—that question has been carefully discussed—"for each decrease in the 0.01 phosphorus." It is desirable, under consent, to raise the carbon by the amount stated. The point is that some mills, in their natural process, obtain Bessemer steel below 0.08 in phosphorus, certainly below 0.10. The result would be if we had, for example, 0.06 phosphorus with the carbon also running low, an abnormally soft rail. On the other hand, some open-hearth mills naturally run their phosphorus down to the neighborhood of 0.01. In such cases as that it is allowable to increase the carbon, under agreement, by 0.03 to each 0.01 in phosphorus below 0.03. However, it is not a requirement in the specification; it is a matter of mutual consent or agreement, after the contract is made or after the work is in progress of making the rails.

The President:—Any additional discussion on No. 5?

Mr. Tinker:—I would like to ask why the Committee changed this specification from the ordinary practice at present. The manufacturers furnish manganese determinations on every fifth heat. This specification requires only two determinations a day. I think it is desirable to have as full information as we can get on all of the elements.

Mr. Churchill:—We find this to be the general practice, and it was agreed to as being such. There may be some exceptional cases, where the determinations are made more often. On the other hand, I want to call to the attention of the members that we have now specified the elements the average of which are to be furnished. In some other specifications this was not called for. Now we have specifically named all these elements, so there may be no misunderstanding. This paragraph was fully discussed between our Committee and the Manufacturers' Committee and agreed to in this form.

The Secretary:—"6. Average Carbon. It is desired that the percentage of carbon in an entire order of rails shall average as high as the mean percentage between the upper and lower limits specified.

"7. Analyses. In order to ascertain whether the chemical composition is in accordance with the requirements, analyses shall be furnished as follows: (a) For Bessemer process the manufacturer shall furnish to the inspector, daily, carbon determinations for each heat before the rails are shipped, and two chemical analyses every 24 hours representing the average of the elements, carbon, manganese, silicon, phosphorus and sulphur contained in the steel, one for each day and night turn, respectively. These analyses shall be made on drillings taken from the ladle test ingot not less than one-eighth inch beneath the surface. (b) For Open-Hearth process, the makers shall furnish the inspectors with a chemical analysis of the elements, carbon, manganese, silicon, phosphorus and sulphur, for each heat. (c) On request of the inspector, the manufacturer shall furnish drillings from the test ingot for check analyses.

"8. Physical Qualities. Tests shall be made to determine: (a) Ductility or toughness as opposed to brittleness. (b) Soundness.

"9. Method of Testing. The physical qualities shall be determined by the Drop Test.

"10. Drop Testing Machine. The drop testing machine used shall be the standard of the American Railway Engineering Association. (a) The tup shall weigh 2,000 lbs., and have a striking face with a radius of 5 inches. (b) The anvil block shall weigh 20,000 lbs., and be supported on springs. (c) The supports for the test pieces shall be spaced three feet between centers and shall be a part of, and firmly secured to, the anvil. The bearing surfaces of the supports shall have a radius of five inches.

"11. Pieces for Drop Test. Drop tests shall be made on pieces of rail not less than four feet and not more than six feet long. These test pieces shall be cut from the top end of the top rail of the ingot, and marked on the base or head with gage marks one inch apart for three inches each side of the center of the test piece, for measuring the ductility of the metal."

Mr. Churchill:—I want to call attention to the fact that the test pieces are to be marked with the gage, on either the head or the base, which allows it to be tested either with head up or head down. I make that note especially, because it is one of the points raised by Mr. Howard. Undoubtedly rails break oftener in track from top of head down. Hence a drop test with top of head down is a safe check. This was made the subject of a special report by Mr. Wickhorst, and you are all familiar with it, I think, as it is given in a recent Bulletin.

The Secretary:—"12. Temperature of Test Pieces. The temperature of the test pieces shall be between 60 and 100 degrees Fahrenheit."

Mr. L. C. Fritch:—That was changed from 120 degrees to 100 degrees, was it not, Mr. Chairman of the Committee? I would like

to know the purpose of that change from 120 degrees, upper limit, to 100 degrees.

Mr. Churchill:—It was felt by many that 120 degrees was too high a limit, and would result in not giving a correct gage on the results of the test; 100 degrees is easily secured, and it was thought advisable to keep the test piece within the lower range at the time the tests were being made.

The Secretary:—"13. Height of Drop. The test piece shall, at the option of the inspector, be placed head or base upward on the supports, and be subjected to impact of the tup falling free from the following heights:

For 70-lb. rail.....16 feet
For 80, 85 and 90-lb. rail.....17 feet
For 100-lb. rail.....18 feet

"14. Elongation or Ductility. Under these impacts the rail under one or more blows shall show at least 6 per cent. elongation for one inch, or 5 per cent. each for two consecutive inches of the six-inch scale, marked as described in Section 11."

Mr. Churchill:—I wish to call the attention of the members to the fact that this is an important addition to general specifications heretofore issued. Mr. Howard referred to this matter. If you will refer to page 818 and page 830 of this Bulletin, in which our specifications are printed, you will find diagrams showing that the elongation and ductility varies with the other tests. We all know that one of the best tests of steel is the elongation and contraction in 8 inches, or 2 inches, as the case may be, in tests of structural steel. We want to use a test for rail that can quickly be made, and at the same time bring out this same comparative information, and if you will refer especially to the diagrams on page 830, you will see that the ductility test shows correspondence to a very fair degree with tensile tests, for example, and on the preceding page you will see comparisons between reduction of area and elongation. In other words, by this ductility test we get a quick means of finding the toughness or ductility of the material in rail somewhat similar in results to those secured by the longer method, impracticable of use, we think, in rail manufacture—that is, the turning down of a specimen, and subjecting it to a test for tensile strength, reduction of area and elongation.

Mr. John G. Sullivan (Canadian Pacific):—I would like to ask two questions: First, I see there is only one limit—"must show at least 6 per cent. elongation." Now, is it not a fact that the elongation bears a direct ratio to the middle ordinate, and is it not easier to measure the middle ordinate in a chord of three feet than it is to measure the elongation by measuring the distance between points and, as the unit will be greater, will you not get more accurate results? This on the assumption that there is a direct ratio between the two.

Mr. Churchill:—We do not agree that there is a direct ratio between the two. We started out a few years ago with the idea that the permanent set would be something of a guide, that it would give an idea of the character and uniformity of the material; but if you will refer to Part 2 of last year's Proceedings, you will find that there were very great variations on the permanent set measurements. Mr. Wickhorst has since reported upon this same matter, and we find, in brief, that the permanent set is not a uniform gage: that the minimum ductility is a better gage, and it is for that reason that it is suggested. The permanent set is given in the next paragraph, and we hope we can fix limits in the course of time to determine that the material is not too soft.

The President:—What is your second question, Mr. Sullivan?

Mr. John G. Sullivan:—That answers the second one.

Mr. R. D. Coombs (Consulting Engineer):—Is there any difference in the result of the test, depending on whether the rail is tested head up or head down?

Mr. Churchill:—Mr. Wickhorst brings that out very plainly in the latter part of this Bulletin. Head down for the upper portion of the rail bar shows a little less elongation than with head up: in the rest of the bar the reverse is true. The safest course is, therefore, to take head down. We have made it allowable for the inspector to make the test either way.

Prof. Walter Loring Webb (Consulting Engineer):—I would like to ask if there should not be some specification as to stiffness of the springs which support the anvil block. It states merely that they should be supported on springs. I think it would make quite a difference whether those springs were abnormally stiff or abnormally easy.

Mr. Churchill:—That is all given in the specifications for the standard drop testing machine adopted by the Association a few years ago.

Mr. R. D. Coombs:—Based upon what the Chairman of the Committee said a moment ago, would it not be desirable, though I do not make this as a motion, to add to that paragraph some statement to the effect that it is desirable to test in one way rather than the other?

The President:—Not at the present time, Mr. Coombs.

The Secretary:—"15. Permanent Set. It is desired that the permanent set after one blow under the drop test shall not exceed that in the following table, and a record shall be made of this information."

Mr. L. C. Fritch:—The Committee, in commenting on section 15, says that it is the intention, when sufficient data are at hand, to prescribe maximum and minimum limits for deflections under the drop test, and that this method of classifying rails is only tentative. I do not think any of us would reject any rails on this specification, and it occurs to me that that paragraph could just as well be left out

of these specifications until we have reached definite conclusions where the maximum and minimum could be fixed. While, of course, it is a question of getting information and records, I believe we can spend our time better in getting physical tests of rails and not include this at the present time until we have reached some definite data that will give us a maximum and a minimum that we can reject rails upon or accept rails.

Mr. Churchill:—I will state that it is easy to measure the permanent set at the time the elongation is measured, and with the elongation secured the permanent set becomes the check on too soft material. We want this information and we hope it will be taken. It is not an item mandatory or as a basis of condemning the rail, but we think that we will soon have a figure for the maximum set to determine when a rail is too soft. We sometimes receive rail that is too soft. Some of us have, I think, within the last two years set aside heats of steel that have been found to be too soft.

The Secretary:—"16. Test to Destruction. The test pieces which do not break under the first or subsequent blows shall be nicked and broken, to determine whether the interior metal is sound."

Mr. Churchill:—I would explain, in behalf of the Committee, that this test shows, first, whether or not the material is too brittle, and the test to "destruction" shows whether enough discard has been made to secure sound material.

Mr. R. D. Coombs:—My question is partly answered, I think, by what Mr. Churchill has just said. My question was in reference to the use of the word "sound." If the metal were really unsound, would not the drop test show it? It is a question of what is meant by "sound."

Mr. Churchill:—No, sir; a pipe rail is not discovered by a simple drop test alone.

The Secretary:—"17. Bessemer Process Drop Tests. One piece shall be tested from each heat of Bessemer steel.

"(a) If the test piece does not break at the first blow and shows the required elongation (Section 14), all of the rails of the heat shall be accepted, provided that the test piece when nicked and broken does not show interior defect.

"(b) If the piece breaks at the first blow, or does not show the required elongation (Section 14), or if the test piece shows the required elongation but when nicked and broken shows interior defect, all of the top rails from that heat shall be rejected.

"(c) A second test shall then be made of a test piece selected by the inspector from the top end of any second rail of the same heat, preferably of the same ingot. If the test piece does not break at the first blow, and shows the required elongation (Section 14), all of the remainder of the rails of the heat shall be accepted, provided that the test piece when nicked and broken does not show interior defect.

"(d) If the piece breaks at the first blow, or does not show the required elongation (Section 14), or if the piece shows the required elongation but when nicked and broken shows interior defect, all of the second rails from that heat shall be rejected.

"(e) A third test shall then be made of a test piece selected by the inspector from the top end of any third rail of the same heat, preferably of the same ingot. If the test piece does not break at the first blow and shows the required elongation (Section 14), all of the remainder of the rails of the heat shall be accepted, provided that the test piece when nicked and broken does not show interior defect.

"(f) If the piece breaks at the first blow, or does not show the required elongation (Section 14), or if the piece shows the required elongation but when nicked and broken shows interior defect, all of the remainder of the rails from that heat shall be rejected."

Mr. Churchill:—In behalf of the Committee, I wish to explain that this method of testing, or rather the additional number of tests, are made primarily to discover, of course, anything that is defective, and secondly, and of almost equal importance, so as not to throw away any good material. We have proved, in the last two years, that the making of tests is very quickly done in this manner and that they are not costly. There is very little expense connected with it. This form of testing can be quickly made; and the result of these three trials, if necessary, on a Bessemer heat of steel, will reduce to a minimum the amount of material that is thrown away and will save all good material.

Prof. Walter Loring Webb:—I do not see the necessity of the words "or subsequent" at the end of the first line of No. 16, because it would seem as if all those tests which follow depend on the first blow. As far as I can see, it does not depend on any subsequent blow.

Mr. Churchill:—That brings out the point I probably should have explained before. In No. 13, the question of ductility is described—how we get it. Now it is conceivable and it often does happen that the full ductility of the metal is not secured under one blow, in an 18-foot drop, therefore we make a second blow. In case we have not 6 per cent. elongation, for example, even a less drop than 18 feet may be used for the second blow. We want to find what is the total ductility of the rail; if it is over 6 per cent. in the inch, it is an acceptable rail under that test. Therefore, there may be more than one blow necessary before the ductility is determined or the rail is broken. Next, if the rail does not break in developing ductility, we want to go on with the breaking to destruction, to find out the character of the inner metal as far as the eye can determine, that is, to find out whether there are any interior flaws.

Mr. W. L. Seddon (Seaboard Air Line):—I would like to ask the Committee whether they have considered at all the breaking of a piece from the top of each ingot for soundness. It seems to me that

the drop test and the breaking of the rail for soundness is all right so far as that ingot goes, but it does not seem to me that that would necessarily tell us anything about the soundness of the top rails of the other ingots.

Mr. Churchill:—The method is the carrying out of the general practice in all steel testing. We do not test every ingot of any structural steel. From our present information we think it would not be possible to keep the mills running and test every individual ingot. We do not say that as a finality. It is certainly in the right line to test more ingots. We propose to test a good deal more under these specifications than we have tested heretofore. We believe that under this testing method—or the expansion of this method later, that we may be able to reduce the chemistry requirements.

Mr. L. C. Fritch:—Mr. Seddon has brought up a point which I was going to touch on after the drop test on the open-hearth had been read, but as he has brought up the point I would like to discuss it now. It seems to me we have reached a point where we ought to quit taking a chance on accepting a lot of rails about which we know nothing, in regard to the soundness of the material. The only way we can arrive at that is to take a test piece from each ingot and test it to destruction. Now, while it is said that this seems to be impracticable, and at the present time will delay the mills in their operation, yet by providing the necessary equipment, it should not take much time. It need not be a test piece of the full length, as specified here. A shorter test piece can be taken, and if it does involve a slightly additional cost, it certainly will be worth the expense. The specifications are a great advance over previous specifications, especially in the open-hearth process, where a test piece from three ingots is required, but if there are sixteen to nineteen or more ingots we have to take a chance on the balance. We know nothing positively about them, and it occurs to me, if we have a test of this kind, including the primary tests mentioned, which are all right as far as that goes, and then require some secondary test made for soundness, something on the following order, it would be desirable:

"In addition to the primary tests above provided, the remaining ingots not tested shall be subjected to the following tests, to insure sound rails from each individual ingot.

"A test piece shall be taken from the 'A' rail and if, when nicked and broken, shows no interior defect, all the rails of that ingot shall be accepted. If, when nicked and broken, it shows interior defects the 'A' rail of that ingot shall be rejected, and a test piece taken from the 'B' rail. If the test piece, when nicked and broken, shows no interior defect, all the remaining rails of the ingot shall be accepted. If the test piece, when nicked and broken, shows interior defects all the rails above and including the 'B' rails of the ingot shall be rejected, and a test piece taken from the 'C' rail and tested in the same manner, and this process shall be continued until the remainder of

the rails of the ingot are tested wherever the presence of interior defects is developed."

Mr. Churchill:—I presume you make that as a suggestion.

Mr. L. C. Fritch:—Simply as a suggestion.

Mr. Churchill:—We would prefer that you turn that suggestion over to us and let us work on it. We think, during the coming year, we can go on with the work along this line. We do not think your suggestion can be carried out at present. The whole intent of paragraphs 17 and 18 is to encourage tests. This Association was responsible, a few years ago, for increasing the number of tests from one in five heats to one in each heat. You know what difficulty we had to convince not only members but the manufacturers as well, that that could be done. The manufacturers and others are modifying their views, and I believe, as we use these specifications, all will soon be in hearty accord in multiplying tests. The same labor force is constantly at the drop testing machine, and I see no reason in the world why, if any question is raised about any ingot or any test, an inspector should not say, "We will go and test the next ingot;" and especially is that true in open-hearth steel, where the heats are larger. But you notice we have provided for three tests in the Bessemer heat, which is far ahead of anything before. The principle that is laid down here, as far as the tests are concerned, is a well-defined principle applied in testing all materials used by railroads and every other class of work. Bridge material is tested in this method, not by every ingot. Wheels are tested by this method, not by every ingot; axles, everything we use, are tested under this general scheme. If we find that a decided improvement can be gained under your suggestion, we are in for it, and I think the manufacturers will be in for it, if we can show that.

Mr. L. C. Fritch:—I do not want to be understood as criticising the Committee in any way.

The President:—They are here for criticism.

Mr. L. C. Fritch:—I think we have made a great improvement, especially on the question of tests on open-hearth steel. I believe this will work both ways. I think we are rejecting a lot of rail now that will be accepted.

Mr. John G. Sullivan:—For information of the Committee, one of our Canadian mills proposed voluntarily that they would sell us rails on the test of top piece at every ingot, at 50 cents per ton extra. Did I correctly understand Mr. Churchill to state that he was going to keep hammering a rail until he got that ductility?

Mr. Churchill:—If the test piece does not break on the first blow, and at the same time.

Mr. John G. Sullivan:—I think we would be getting on dangerous ground. I would be very much afraid of that.

Mr. Churchill:—Why so? It is the same process that we adopted in getting the ductility, under the static test; we carry it out to a

failure. I think it would be a mistake to say that a rail must show a given ductility as a minimum, with an 18-foot drop. I speak now of 100-lb. rail. If that rail will stand the 18-foot drop, we have not at that time gotten a measure of what the ductility is. Hence, another drop may be made, though it may be of less height than 18 feet. It is shown by withstanding the first drop that it is not brittle, but we have not the full measure of the ductility.

Mr. John G. Sullivan:—What I would be afraid of would be this: I think we all agree that the drop test is the physical check on chemical composition, and if the material is at all uniform we should get a uniform deflection or percentage of ductility with a uniform weight dropping a uniform distance. If, however, the majority of the rails gave prescribed results on receiving one blow, it would indicate to my mind that the rail that had to be hit two or three times was either high in phosphorus or carbon, and that while that particular piece might stand this treatment, I would be afraid of some of the other rails from the same heat of ingot.

Mr. Churchill:—Remember this is the top rail of the ingot, which is in all probability the worst piece there is.

Mr. John G. Sullivan:—I had never heard of that second dropping before, and I should like to ask for information, have any rails been accepted under that specification?

Mr. Churchill:—Yes.

Mr. John G. Sullivan:—How many of those have to be hit half a dozen times or twice to get ductility? Is it the general thing or the exception? If it is the exception, I would be afraid of it.

Mr. George W. Kittredge (New York Central & Hudson River):—For the information of the Association, the specifications of the New York Central Lines have required subsequent blows if the ductility is not brought out on the first blow. All the rails accepted by the New York Central Lines have been subjected to that test for a great many years.

Mr. Seddon:—Do I understand, if one of these three rails breaks and the other two stand up, that the whole heat is accepted?

Mr. Churchill:—This is accepting an ingot on the best two out of three. We had only one test heretofore; now we get three.

Mr. Seddon:—You are accepting something where one shows bad.

Mr. Churchill:—We would not use the bad one. The top rail would be discarded.

Mr. Seddon:—The top rail of that single ingot?

Mr. Churchill:—Yes, sir.

The Secretary:—"18. Open-Hearth Process Drop Tests. Test pieces shall be selected from the second, middle and last full ingot of each open-hearth heat.

"(a) If two of these test pieces do not break at the first blow and show the required elongation (Section 14), all of the rails of the

heat shall be accepted, provided that these test pieces when nicked and broken do not show interior defect.

"(b) If two of the test pieces break at the first blow, or do not show the required elongation, or if any of the pieces that have been tested under the drop when nicked and broken show interior defect, all of the top rails from that heat shall be rejected.

"(c) Second tests shall then be made from three test pieces selected by the inspector from the top end of any second rails of the same heat, preferably of the same ingots. If two of these test pieces do not break at the first blow and show the required elongation (Section 14), all of the remainder of the rails of the heat shall be accepted, provided that the pieces that have been tested under the drop when nicked and broken do not show interior defect.

"(d) If two of these test pieces break at the first blow or do not show the required elongation (Section 14), or if any of the pieces that have been tested under the drop when nicked and broken show interior defect, all of the second rails of the heat shall be rejected.

"(e) Third tests shall then be made from three test pieces selected by the inspector from the top end of any third rails of the same heat, preferably of the same ingots. If two of these test pieces do not break at the first blow, and show the required elongation (Section 14), all of the remainder of the rails of the heat shall be accepted, provided that the pieces that have been tested under the drop when nicked and broken do not show interior defect.

"(f) If two of these test pieces break at the first blow or do not show the required elongation (Section 14), or if any of the pieces that have been tested under the drop when nicked and broken show interior defect, all of the remainder of the rails from that heat shall be rejected.

"19. No. 1 Rails. No. 1 classification rails shall be free from injurious defects and flaws of all kinds.

"20. No. 2 Rails. (a) Rails, which, by reason of surface imperfections, or for causes mentioned in Section 30 hereof, are not classed as No. 1 rails, will be accepted as No. 2 rails, but No. 2 rails which contain imperfections in such number or of such character as will, in the judgment of the inspector, render them unfit for recognized No. 2 uses, will not be accepted for shipment.

"(b) No. 2 rails to the extent of 5 per cent. of the whole order will be received. All rails accepted as No. 2 rails shall have the ends painted white and shall have two prick punch marks on the side of the web near the heat number near the end of the rail, so placed as not to be covered by the splice bars.

"21. Quality of Manufacture. The entire process of manufacture shall be in accordance with the best current state of the art.

"22. Bled Ingots. Bled ingots shall not be used.

"23. Discard. There shall be sheared from the end of the bloom, formed from the top of the ingot, sufficient metal to secure sound rails."

Mr. Seddon:—Is there not some possibility of going to the 39-foot rail?

The President:—The question of longer rails is being studied.

Mr. Seddon:—I think we ought to try to get a longer rail.

The President:—That is under investigation.

Mr. W. F. Steffens (Boston & Albany):—Is it necessary to include any statement as to the fact that this 10 per cent. of short rails shall not come at one time? In a case with which the Chairman is acquainted the manufacturers tried to ship the entire order of shorts first.

Mr. Churchill:—I do not see how we can control that matter. It is one of the things that can be fixed in the contract between the buyer and the purchaser under mutual agreement.

The Secretary:—"24. Lengths. The standard length of rails shall be 33 feet, at a temperature of 60 degrees Fahrenheit. Ten per cent. of the entire order will be accepted in shorter lengths varying by 1 foot from 32 feet to 25 feet. A variation of ¼ inch from the specified lengths will be allowed. No. 1 rails less than 33 feet long shall be painted green on both ends.

"25. Shrinkage. The number of passes and speed of train shall be so regulated that on leaving the rolls at the final pass, the temperature of the rail will not exceed that which requires a shrinkage allowance at the hot saws, for a rail 33 feet in length and of 100 lbs. section, of 6¾ inches and ⅛ inch less for each 10 lbs. decrease in section.

"26. Cooling. The bars shall not be held for the purpose of reducing their temperature, nor shall any artificial means of cooling them be used after they leave the finishing pass. Rails, while on the cooling beds, shall be protected from snow and water.

"27. Section. The section of rails shall conform as accurately as possible to the template furnished by the Railroad Company. A variation in height of 1/64 inch less or 1/32 inch greater than the specified height, and 1/16 inch in width of flange, will be permitted; but no variation shall be allowed in the dimensions affecting the fit of the splice bars."

Mr. Lindsay:—What can be done to check the overfilling or the underfilling of the head of the rail? Very often we get a rail with too much metal in the center of the head or too little metal in the center of the head, and while it might comply with the specifications as to height, it would be objectionable.

Mr. Churchill:—I think the careful using of the template on the part of the inspectors will result in checking that. These are the usual limits.

The Secretary:—"28. Weight. The weight of the rails specified in the order shall be maintained as nearly as possible, after complying with the preceding section. A variation of one-half of 1 per cent. from the calculated weight of section, as applied to an entire order, will be allowed.

"29. Payment. Rails will be accepted and paid for according to actual weights."

Mr. L. C. Fritch:—It occurred to me that Section 29 would read a little better if it were changed to read, "Rails accepted will be paid for according to actual weights."

Mr. Churchill:—We accept that.

The Secretary:—"30. Straightening. The hot straightening shall be carefully done, so that gagging under the cold presses will be reduced to a minimum. Any rail coming to the straightening presses showing sharp kinks or greater camber than that indicated by a middle ordinate of 4 inches in 33 feet, for A. R. A. type of sections, or 5 inches for A. S. C. E. type of sections, will be at once classed as a No. 2 rail. The distance between the supports of rails in the straightening presses shall not be less than 42 inches. The supports shall have flat surfaces and be out of wind.

"31. Drilling. Circular holes for joint bolts shall be drilled to conform accurately in every respect to the drawing and dimensions furnished by the Railroad Company.

"32. Finishing. (a) All rails shall be smooth on the heads, straight in line and surface, and without any twists, waves or kinks. They shall be sawed square at the ends, a variation of not more than 1/32 inch being allowed; and burrs shall be carefully removed.

"(b) Rails improperly drilled or straightened, or from which the burrs have not been removed, shall be rejected, but may be accepted after being properly finished.

"33. Branding. The name of the manufacturer, the weight and type of rail, and the month and year of manufacture shall be rolled in raised letters and figures on the side of the web. The number of the heat and a letter indicating the portion of the ingot from which the rail was made shall be plainly stamped on the web of each rail, where it will not be covered by the splice bars. The top rails shall be lettered 'A,' and the succeeding ones 'B,' 'C,' 'D,' etc., consecutively; but in case of a top discard of 20 or more per cent., the letter 'A' will be omitted. Open-hearth rails shall be branded or stamped 'O. H.' All markings of rails shall be done so effectively that the marks may be read as long as the rails are in service.

"34. Separate Classes. All classes of rails shall be kept separate from each other.

"35. Loading. All rails shall be loaded in the presence of the inspector."

Prof. Walter Loring Webb:—I would like to ask why, at the beginning of Section 26, the word "bars" is used instead of "rails"?

Mr. Churchill:—Those are not yet rails. They are in the process of being made rails; therefore, they are bars.

The President:—Does anyone wish to make any remarks on these specifications before a motion is put for their adoption?

Mr. L. C. Fritch:—Mr. Chairman, I move that the specifications, as amended, be adopted.

The President:—For printing in the Manual?

Mr. L. C. Fritch:—Yes, sir.

The President:—Any remarks on the motion?

(The motion was carried.)

The President:—The Committee is dismissed with the thanks of the Association.

DISCUSSION ON WOOD PRESERVATION.

(For Report, see pp. 863-872.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON WOOD PRESERVATION.

S. R. Church.	L. C. Fritch.	C. H. Spencer.
R. D. Coombs.	V. K. Hendricks.	Earl Stimson.
L. G. Curtis.	C. E. Lindsay.	Dr. Hermann von Schrenk.
S. B. Fisher.	Hunter McDonald.	Walter Loring Webb.
E. A. Frink.	W. L. Seddon.	S. N. Williams.

The President:—The next report is that of the Committee on Wood Preservation, Mr. Earl Stimson, Chairman. We will have the opening statement by Mr. Stimson.

Mr. Earl Stimson (Baltimore & Ohio):—Mr. Chairman, before taking up the consideration of the report, I want to call attention to a few typographical errors. On page 863, under "Work assigned by Board of Direction," paragraph 3, second line, the sixth word should be "gas." On page 864, from the top of the page, paragraph 3, the second line, the word "beeches" should be "beech." In the same line, next to the last word, the word "hardwood," should be "heartwood." On page 865, under "Revision of adopted Specifications for Creosote Oil," the clause in the fourth line, under "standard specifications for creosote oil," namely, "including coal-gas tar or coke-oven tar," should be placed after the word "tar" in the third line, making that line read, "and shall be free from any tar, including coal-gas tar and coke-oven tar, or oil or residue," etc. The same correction is to be made under Specifications for No. 2 Grade Creosote Oil, the changes occurring in the same lines, and also the same correction under Specifications for No. 3 Grade Creosote Oil. With these corrections we will take up the consideration of our report.

The Board of Direction assigned eight subjects for the consideration of the Committee. Following the instructions with reference to making up reports, we selected two of these subjects upon which to report conclusions. These two subjects are: "the grouping of timbers for antiseptic treatment," and "the revision of the adopted Specifications for Creosote Oil."

Under the grouping of timbers for antiseptic treatment, I will state that arrangements were made last year for a series of co-operative experiments at various plants to determine the best method of grouping different species in different regions. These tests are not completed, but progress to date is reported in Appendix E of this report. "Past experience has demonstrated and your Committee recom-

mends that such principles as have received recognition in standard practice be embodied in the Manual." These principles are given in this paragraph, there being four. Another subject which received consideration of the Committee, and which, to my mind, is of great importance and interest to the Association, is the record of service tests. Last year the Committee recommended, and the recommendation was adopted, that certain sections of track be selected on each railroad for the purpose of making accurate tests, covering the life of treated and untreated ties. We wrote to various roads making inquiries as to whether such tests had been inaugurated, and, if so, to obtain data and information bearing on such tests. In Appendix B you will find this information tabulated. It is the intention of the Committee that this form a nucleus of a permanent record of service tests, to be added to from year to year.

Aside from the tests reported in this tabulated statement, we received too late to include in it, the record of forty service tests from the Forest Service. These will be added to this record and published next year. The Committee is going to make a very strenuous effort to keep up this record and make it as complete as possible. It is hoped it will form a source of very valuable information to the Association.

Your Committee was also instructed to investigate the merits of various preservatives, specifying oil from water gas tar and the use of refined coal-tar in creosote oil. While the Committee instituted investigations along these lines, it does not feel in a position this year to make a report. If so ordered by the Board of Direction, our investigations will be continued during the coming year and a report will be made at some subsequent meeting.

The second subject upon which the Committee reports in a definite manner is "the revision of adopted Specifications for Creosote Oil." We will take this up later.

On other matters which were assigned to the Committee for consideration we report progress. These are forms for reporting inspection, the impregnation of crude oil, and the value of brush coating and dipping. There was not very much information to be found on these subjects, and we will continue our hunt for more during the coming year.

The Committee was further asked to prepare specifications for impregnation with creosote oil. A specification has already been adopted by the Association and is contained in the Manual. As this specification represents good practice, the Committee does not recommend any changes in it. With the consent of the Chair and the Association we will now consider our recommendations for this year. These will be found on page 864, the four principles recommended for the grouping of timbers for treatment. These we present for adoption by the Association, for insertion in the Manual.

"(1) Ties of approximately the same period of seasoning should be grouped together for treatment; green ties should never be mixed with seasoned ones."

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—Mr. Chairman, I understand the province of this Committee is that of wood preservation. There seems to be a tendency on the part of the Committee to confine its activities entirely to ties. Should not that first clause refer to something else besides ties? I think it is just as important to group dimension timber as it is ties.

The President:—It is intended to cover all kinds of wood.

Mr. McDonald:—I think it should be made to read that way then.

Mr. Earl Stimson:—This grouping applies more particularly to ties rather than the longer timbers. The bulk of the timber treating for railroads is confined to ties, and from a railroad standpoint the treatment of ties at the present time is the one of greatest interest.

Mr. McDonald:—There is no doubt about that, but the point I make is if this Committee's province is considered tie preservation only, then this clause is right and proper, but if it is timber preservation, it should be made inclusive of all kinds of timber.

Mr. Earl Stimson:—We can, by a very simple process, widen the scope of our recommendations by substituting the word "timbers" for "ties," if that is what the Association wants. I move that the first recommendation, as presented, be adopted.

The President:—The first conclusion is on page 867, but it refers to four headings, on page 884. I will ask the chairman to read each one separately, as the motion applies to each one separately.

Mr. Earl Stimson:—"(2) Pine ties should be separated on the basis of hardwood and sapwood; it would also be advisable in some cases to group hardwood on the same basis, but it is not generally practical to do so.

"(3) Grouping on the basis of species and families, as, for example, red oaks, pines, beech, etc., if a further division into heartwood classes is made with pine, is usually a satisfactory practice. From this it follows that red oak, beech, long-leaf pine, loblolly pine and gum should be treated separately. Birch and hard maples and certain other combinations, depending on the locality, can be grouped together to advantage.

"(4) The separation in the yard, on the basis the ties are to be grouped for treatment, is an essential and economical practice."

Mr. C. E. Lindsay (New York Central & Hudson River):—Does paragraph 4 refer to the storage yard only?

Mr. Earl Stimson:—Yes, sir. I move the adoption of paragraph 4.

(The motion was carried.)

The President:—Next is page 867, conclusion No. 2. Before making any motion I will ask the chairman to read each one of them separately and make a separate motion.

Mr. Earl Stimson:—The only change in the standard specification for creosote oil is with reference to specifically excluding coal-gas tar and coke-oven tar. I will read the present specification and then as it is revised:

"The oil used shall be the best obtainable grade of coal-tar creosote; that is, it shall be a pure product obtained from coal gas tar or coke oven tar and shall be free from any tar, including coal gas tar or coke oven tar, oil or residue obtained from petroleum or any other source; it shall be completely liquid at thirty-eight (38) degrees centigrade and shall be free from suspended matter; the specific gravity of the oil at thirty-eight (38) degrees centigrade shall be at least 1.03. When distilled by the common method—that is, using an eight (8) ounce retort, asbestos covered, with standard thermometer, bulb one-half (½) inch above the surface of the oil—the creosote, calculated on the basis of the dry oil, shall give no distillate below two hundred (200) degrees centigrade, nor more than five (5) per cent. below two hundred and ten (210) degrees centigrade, not more than twenty-five (25) per cent. below two hundred and thirty-five (235) degrees centigrade, and the residue above three hundred and fifty-five (355) degrees centigrade, if it exceeds five (5) per cent. in quantity, shall be soft. The oil shall not contain more than three (3) per cent. water."

I move that this change in the specifications be adopted.

(The motion was carried.)

Mr. Earl Stimson:—There seems to be a demand for a specification for creosote oil somewhat less stringent than our standard specification. In fact, it seems necessary to have such a specification in order to meet the grade of oil that we are oftentimes obliged to purchase. For this purpose the Committee submits specifications for a No. 2 grade oil and for a No. 3 grade oil. The specification for the No. 2 grade creosote oil reads as follows:

"The oil used shall be the best obtainable grade of coal-tar creosote; that is, it shall be a pure product obtained from coal gas tar or coke oven tar, and shall be free from any tar, including coal gas tar or coke oven tar, oil or residue obtained from petroleum or any other source; it shall be completely liquid at thirty-eight (38) degrees centigrade and shall be free from suspended matter; the specific gravity of the oil at thirty-eight (38) degrees centigrade shall be at least 1.03. When distilled by the common method—that is, using an eight (8) ounce retort, asbestos covered, with standard thermometer, bulb one-half (½) inch above the surface of the oil—the creosote, calculated on the basis of the dry oil, shall give not more than eight (8) per cent. distillate below two hundred and ten (210) degrees centigrade, not more than thirty-five (35) per cent. below two hundred and thirty-five (235) degrees centigrade, and the residue above three hundred and fifty-five (355) degrees centigrade, if it ex-

ceeds five (5) per cent. in quantity, shall be soft. The oil shall not contain more than three per cent. water."

I move the adoption of this specification for a No. 2 grade creosote oil.

Mr. L. C. Fritch (Chicago Great Western):—I would like to have some information on the real purpose of drawing these two separate specifications for creosote oil. What will be the difference in the cost between the specifications No. 2 and No. 3?

Mr. Earl Stimson:—I do not think we are prepared to state just what will be the cost. That is a matter depending on market price. As I understand the creosote situation, we are very seldom able to get a creosote oil that conforms strictly with the standard specification. Still the inference is that we pay the same for it as for the high-grade oil. Now the idea is that we place the modified specifications in the hands of our Purchasing Agent, and if he cannot get the oil according to the standard specification, he will be able to accept one that will meet one or the other of the modified specifications, with some corresponding modification in price.

Mr. L. C. Fritch:—I think three grades are too many; two in most cases are enough. It seems to me we should insist upon the very best grade of creosote oil. That is the very life of our timber treatment. We are all investing a lot of money in it, and we should not accept inferior oils. I think we should consider very carefully the adoption of three grades. I realize at times it is difficult to secure the first grade, but it seems to me the third grade is too low for us to accept. A slight difference in the grade of the oil will seriously affect the treatment, while the difference in the cost of the oil will be very slight. So we will be throwing away a lot of the value of our timber treatment by accepting an inferior grade of oil.

Mr. Earl Stimson:—As a matter of fact, there is now quite a large quantity of oil that comes within the No. 3 grade that is being purchased at the standard grade price. This revision of the specifications was given very careful consideration by the sub-committee, composed of some of the leading lights in the timber treating world, men who are specialists in that line, and as long as the discussion is started, I will call upon the chairman of the sub-committee that drafted these specifications to defend any attacks made upon them. Mr. Hendricks, will you please explain to the Association just why we recommend these three grades?

Mr. V. K. Hendricks (St. Louis & San Francisco):—Some of the roads are getting a grade of creosote that will not come under No. 2 and will come under No. 3, and they have to have the creosote, and that was the reason the third grade was recommended by the Committee. For instance, the Chicago & Northwestern is forced to take creosote that does not come within No. 2. That was the reason for adopting the third specifications.

Prof. S. N. Williams (Cornell College):—I would like to inquire if the Committee would please give us an approximate idea of the difference in values of these three grades.

Mr. Hendricks:—The Committee is not able to do that. There is too much that is unknown about the value of creosote, and the valuable constituents of it. The Committee did at one time consider the question of trying to assign relative merits to the different specifications, but it was entirely impracticable to do so with the present knowledge.

Prof. Williams:—Is there much difference in the cost?

Mr. Hendricks:—That depends upon the market conditions and the location, so that we do not see that we can give any information on that question.

Mr. W. L. Seddon (Seaboard Air Line):—I think the way to look at this is not so much the question of the difference in the cost of the oil, but as to how the low-grade oils will act in preserving the timber, whether timber treated with No. 2 oil will stand as much as timber treated with No. 1 oil, and whether timber treated with No. 2 will stand as much as with No. 3. Before we recommend No. 2 and No. 3 oil specifications, we ought to have some information with reference to what the effect on the timber is going to be.

Mr. Earl Stimson:—Most of us are now using oil corresponding to the proposed No. 2 or No. 3 oil and have gotten very good results. Dr. von Schrenk will please explain this question more fully.

Dr. Hermann von Schrenk (Consulting Timber Engineer):—Personally, I have always advocated the use of strictly No. 1 high-grade specification oils, on account of the desirability of getting the very best that we can possibly find. The Committee find, however, that for several years, owing to the tremendous increase in the creosoting industry in this country, and owing to the absence of a sufficient supply of high-grade standard oil, a great many railroads were buying (using the present standard specification) creosote oil which, as a matter of fact, did not come up to it. In other words, we had a state of affairs of having the Purchasing Agent sent out to purchase a material under a specification, and as one Chief Engineer expressed it, "When we asked him whether the oil he obtained came up to that specification, he said, 'Why, we buy it under the specification but it by no means meets it.'" I asked him, "What do you do?" He said, "We make a terrible fuss about it and then we take it." The object of the specifications Nos. 2 and 3 was largely to do away with that rather anomalous situation. I think the Committee pointed out, in the middle of page 865, answering one of the questions put, that in using specifications Nos. 2 and 3, it should be understood that if they have to be used, consideration should be given to the use of greater quantities of creosote oil per cubic foot of wood, than would be used if specification No. 1 is used. The Committee meant to give the impression that wherever possible the railroad company should

try to buy under the specification No. 1, and where that could not be obtained they should try No. 2, and where they could not get No. 2, they should buy No. 3, with the understanding that they would use more of it per cubic foot. In presenting grades 2 and 3 we wish to have it clearly understood that they are inferior in value to No. 1 specification, but nevertheless they might be used, and we would get away from the anomalous position of depreciating the value of No. 1 specification, and get a price reduction.

Mr. L. C. Fritch:—It seems to me we ought to stick to our standard specifications for one grade of oil until we have had some experience as to the effect of No. 2 and No. 3 grade oil. If any one is asking for bids on No. 1 and getting No. 2 or No. 3, he should investigate it. The proper proceeding might be to refer specifications No. 2 and No. 3 back to the Committee for a report next year, and so, in the light of this information, the Association can act upon the adoption of the other specification. Also, whether it would not be sufficient to have a standard specification on No. 1 and No. 2. It seems to me we will lower our standard in accepting so many grades.

Mr. E. A. Frink (Seaboard Air Line):—It seems to me the one purpose is to get as long life as we can of the timber treated. We ought to find out, first, whether No. 2 grade will give as long life as No. 1. If not, we want No. 1; and usually it is the case where a sustained demand is made for one product, we get that product. I understand the known sources of supply are not utilized. Enormous amounts go to waste every year in this country. If there were a demand for that No. 1 grade, I think the supply would soon fill it.

Mr. Lindsay:—I would like to ask Dr. von Schrenk, is it practicable to refine the No. 2 and No. 3 grades up to the standard of No. 1?

Dr. von Schrenk:—No, sir; if that were the case we would insist absolutely on No. 1. I think I voice the sentiment of the Committee when I say that we should all stand absolutely for the highest grade standard. In other words, we want to recommend that as the standard that should be used and the inclusion of grades 2 and 3 is simply recognizing the natural state of affairs. The natural state of affairs is that these oils cannot be bought under No. 1 specifications, because they are not there; they do not exist. I think we ought to stand by our high-grade specifications, but the grades 2 and 3 are simply given to help out those roads which, for geographical or other reasons, are unable to get No. 1 creosote oil, and with the warning, if they buy creosote oil, they ought to approximate No. 1 standard.

Mr. S. B. Fisher (Missouri, Kansas & Texas):—There is another reason why I think we should have the lower grades of creosote. The indications with us are that soft ties will wear out before they decay, and we may wish to get cheaper grades of creosote to preserve those ties until they wear out. For that reason I am in favor of lower grades of creosote.

Mr. R. D. Coombs (Consulting Engineer):—It seems to me the question is largely one of money. It may be perfectly proper to use a cheaper grade of oil for a cheaper class of work, and I would suggest that the Committee might properly advise the relative ultimate cost of work of different grades, taking into account the larger quantity of the cheaper grades.

(The President put the motion for the adoption of specification No. 2, and a vive voce vote was indecisive; whereupon a rising vote was taken, resulting in 83 votes in the affirmative and 7 in the negative.)

Mr. Earl Stimson:—"The oil shall be the best obtainable grade of coal tar creosote; that is, it shall be a pure product obtained from coal gas tar or coke oven tar and shall be free from any tar, including coal gas tar or coke oven tar, oil or residue obtained from petroleum or any other source; it shall be completely liquid at thirty-eight (38) degrees centigrade and shall be free from suspended matter; the specific gracity of the oil at thirty-eight (38) degrees centigrade shall be at least 1.025. When distilled by the common method—that is, using an eight (8) ounce retort, asbestos covered, with standard thermometer, bulb one-half (½) inch above the surface of the oil—the creosote, calculated on the basis of the dry oil, shall give not more than ten (10) per cent. distillate below two hundred and ten (210) degrees centigrade, not more than forty (40) per cent. below two hundred and thirty-five (235) degrees centigrade, and the residue above three hundred and fifty-five (355) degrees centigrade, if it exceeds five (5) per cent. in quantity, shall be soft. The oil shall not contain more than three (3) per cent. water."

I move the adoption of the specification for the third grade creosote oil.

Mr. C. H. Spencer (Washington Terminal Company):—I suppose what I have to say will do no good. I have always stood for good practice. I do not believe the adoption of these low-grade oils constitutes good practice. Dr. von Schrenk told us a few moments ago, or indicated to us, that the difficulty is going to be met by using more oil in the tie. I would like to ask, for information, if it is a fact that those in charge of the creosoting plants are able to, or if they actually will, use more of the lower-grade oil to meet the difficulties?

I feel that we are going to be met, when we specify the No. 1 specification for our ties, by the question, "Why will not the No. 2 or the No. 3 do?" The Committee in making this report does not give us any basis on which we can make a reply to this question. What are we going to say as to the relative values of this oil? What reply are we going to make when we are asked as to the relative life of a tie that is creosoted with No. 2 oil or No. 3 oil, as compared with No. 1? Or what reply will we make to a question as to the cost, the relative values?

I really believe that the suggestion made by Mr. Fritch should have been carried out, that this matter be referred back to the Committee for further consideration and report, that we might have a clearer idea of what we are doing when we are specifying No. 1. Therefore, Mr. Chairman, unless sufficient explanation can be made, I wish to amend that motion that has just been made, to the effect that specification for No. 3 oil be referred back to the Committee for further consideration and report as to quality and values of the creosote specified.

Mr. L. C. Fritch:—In seconding the amendment I would like to say that many of us are treating our timber with all the oil we can get into it. How are you going to get more oil of the lower grade into the timber when we specify the use of all the oil you can get into it? You are up to the point of the limit of penetrability. I do not think that argument will stand.

As far as the refinement of the oil is concerned, I question whether it is not possible to refine the lower grade oil into higher grades; it is a matter of distillation.

I think we are making a mistake to open the doors to an inferior grade of oil, and I hope the amendment, for No. 3 being referred back to the Committee, will carry.

Mr. Hendricks:—How long do your ties last, treated with all the creosote oil that can be put in?

Mr. Earl Stimson:—I also ask Mr. Fritch whether he knows he is getting the standard grade creosote?

In answer to Mr. Spencer, this Committee does not feel as though it is recommending to the Association any poor practice. We are merely submitting specifications that meet the conditions that are imposed upon the users of creosote oil.

Mr. L. C. Fritch:—In answer to the Chairman of the Committee, I wish to say that if I am not getting first-grade creosote oil it is my fault, and it is the fault of every other railway man who has this matter in charge, if he does not get first-grade creosote oil when he buys that grade. You do not analyze it and test it properly, or you would know whether or not you get first-grade oil.

In regard to the suggestion of the Committee, I think it is very valuable, but there is a commercial condition which we must meet, and I do not think we are prepared to meet it now. We have not enough light on the subject and we are simply asking for a little more time so that the subject may be thoroughly investigated in order that we do not make a mistake when we take action.

Prof. Williams:—It seems to me the object of the amendment has been provided for by the Committee itself, as you will see by reference to page 866, where it says that samples are to be submitted to the various railways for analysis and the information to be reported to the Association next year.

Mr. C. H. Spencer:—I submit that this Association is not organized for the purpose of meeting all of the conditions that obtain on the various railways of the country. We are here to recommend good practice to our railways and not to meet all the conditions, which, for various reasons, different railways have to contend with.

Prof. Walter Loring Webb (Consulting Engineer):—I think the question involved here is like the question of buying different grades of lumber. It would be very nice to always use the highest grade of lumber, but we cannot. It is a matter of practical business. As I understand, from what these experts have told us regarding creosote oil, some creosote oil will always be of a relatively lower grade, as it comes out of the still. There will always be a market for it, and if railways want to use that lower grade, just as they may want to use the lower grades of lumber, we have simply to provide specifications so that these different grades can be used properly. We do not recommend that any railway shall use this third grade of creosote oil, but we simply define what the third grade of creosote oil shall be, just as we define the various grades of lumber.

Mr. Seddon:—We do know something about the comparative life and usefulness of various grades of lumber, and we are willing to consider various grades of creosote oil if we know something about them, but at the present time the Committee is not prepared to tell us either their value or the effect upon the timber, and I do not think this Association should recommend creosote specifications unless the Committee can put us in the possession of such information as will enable us to go to the Chief Engineer, or the responsible official of the railway, and say, "Let us buy No. 3 creosote oil, and we will get such and such results from its use." I confess there is nothing here in this report that I can see that gives us that information.

Mr. Earl Stimson:—I wish, in answer to that statement, to say that we feel these specifications are all right, and meet the conditions that confront Purchasing Agents when they go into the market to buy creosote oil. We do say that we are not prepared to state how many cents less per gallon the grades of oil No. 2 and 3 will cost as compared with the standard grade, or how many years, more or less, the ties which are treated with No. 2 and No. 3 oil will last as compared with the standard grade oil. This must be determined by practical experience. No doubt many of the good results obtained on railways in creosoting have been obtained by the use of an oil below the standard grade, but conforming to the proposed No. 2 and No. 3 grade of creosote oil.

I have the greatest confidence in my Committee. (Applause). I will say right here that most of these gentlemen on this Committee know a great deal more about the creosote business than I do, and than most of those present do, because they have been associated with the scientific study and practical use of creosote oil for many years, therefore, I most earnestly recommend to the Association the

adoption of the recommendations of this Committee. In a way, I infer that possibly some of the speakers have not had quite as broad an experience with this subject as some of the members of this Committee (Applause), and, for this reason I feel all the more justified in urging our recommendations for adoption.

Mr. L. C. Fritch:—We appreciate the fact many of us are ignorant on this subject, but the confession of ignorance is oftentimes the first step to finding out something about a thing. The chairman has said it is for the Purchasing Agent that these specifications are made. How about the Engineers? The Engineer must use the creosote oil. The Purchasing Agent will say to the Engineer: "Shall we buy No. 1, No. 2, or No. 3 oil?" What can the Engineer say in answer to that question? The Engineer does not know the values of these respective grades of oil for treating timber. We want to know what we are doing before we adopt these specifications.

Mr. Earl Stimson:—In answer to that last remark, let the Purchasing Agent get bids. That is really the only way we can tell regarding the respective costs of these different grades of oil.

Mr. L. G. Curtis (Baltimore & Ohio):—It looks to me that the only way we can tell as to what the No. 1 grade is worth, what the No. 2 grade is worth, and what the No. 3 grade is worth is to adopt the specifications and then try them out. It is just as certain of our members have said, and certain members of the Committee have said, that there have been a great many ties treated, but we do not know what has gone into them. Now, let us put these specifications into effect and find out what the result really is.

Mr. Lindsay:—As I understand it, the difference between specification No. 2 and specification No. 3 is only a small percentage in specific gravity; one is 1.03 and the other 1.025. I ask Dr. von Schrenk what percentage of the total output of creosote oil would be rejected if he did not have No. 3 specification?

Dr. von Schrenk:—That is almost impossible to answer, because the volume of oils differ from week to week and month to month, depending on the fluctuation of the production of the output, and on peculiar accidents which occur in the distilling operation. The only reason why a very small difference is made in the specifications is simply to give an actual specification for the actual oil as we find the railways actually buying in millions of gallons every week. To further justify these specifications—I feel that really we are getting very finicky on these specifications of creosote oil—I will say that I made a trip over some English railways not very long ago and I find specifications in use in England that run all the way from away above our standard specification to away below our No. 3, and they have been using some of that oil for forty years and the ties in many cases have been twenty-five and thirty years in use on the English railways.

As the Chairman has stated, we are not recommending anything that will be at all dangerous or experimental, but oils of the character of grades Nos. 2 and 3 have been used for from 75 to 100 years or more the world over and a lot of them have been worse than the No. 2 and 3 grade, and all we are doing is to endeavor to get an opportunity for some of the oils to be used with positive recommendations concerning their use.

The statement has been made by one of the speakers that some of us are pumping our timber full of oil. If the timber is being pumped full of standard creosote oil, very well; but if they are pumping the timber full of No. 2 and 3, the answer which may be made to that is if they pump full of No. 1, they are spending more money than is necessary, and the maximum amount that can be pumped in of No. 3 is about what should go in. I do not think we are recommending anything experimental or doubtful.

The President:—Is Mr. S. R. Church, Manager of the Railroad Department of the Barrett Manufacturing Company, of New York, present?

Mr. S. R. Church:—I thank you, Mr. Chairman, for an opportunity to speak on the subject in which I am very much interested indeed; and I think what Dr. von Schrenk has just said has probably done more to enlighten some of you who are not particularly well posted on this matter than anything the Committee has said before. The point is there is really no essential difference between the three grades of oil which your Committee has recommended. They are all pure coal-tar creosotes. I think I can say without fear of contradiction that the reputation of coal-tar creosote as a preservative, both abroad and in this country, was established before any oil of as high specific gravity, or with as high distillation range as your standard specification requires, was produced or was in use, that is, in large quantities. Therefore, the recommendation for these three grades does not involve any experiment. It is simply, as your Committee has already stated, a matter of recognizing existing conditions and enabling a road to have a specification which can be met by the oil producer.

The question has been raised as to whether it will be possible to refine any of these oils of lower distillation range to make them comply with specification No. 1. That could be done, but only at the expense of a large loss of creosote oil, and increasing, therefore, the cost of the preservative.

It is not true, as someone stated, that there is any surplus of raw material in this country from which creosote oil can be obtained. The amount of tar going to waste is very negligible. The manufacturers are doing everything in their power to get the highest possible percentage of creosote and the best possible quality of creosote from the tar. We are continually endeavoring to obtain enlarged outlets for the by-

product which results in the manufacture of high-grade creosote, and I feel safe in saying that the average quality of the creosote will improve with time. I also feel safe in saying that the average quality of the creosote produced to-day is of proven value and that timbers treated with enough of the preservative, using any of these three oils, need cause no anxiety as to their life.

Mr. Lindsay:—I ask if there is any difference in the degree of penetration of dense woods in the use of the lighter oils—will the lighter oil penetrate any more deeply in the dense wood than the oil covered by the No. 1 specification?

Mr. Earl Stimson:—I will answer that by saying no.

The President:—The motion for adoption has been amended to one for recommittal with instructions, and we will vote on the amendment first, if the discussion is finished.

(The question was put, and the motion was lost.)

The President:—We will now vote on the motion to adopt the recommendation of the Committee covering No. 3 grade creosote oil.

(The motion was carried.)

Mr. Earl Stimson:—I now move the adoption of the third conclusion of the Committee which reads: "That the heading 'Specifications for Analysis of Creosote Oil,' as it now stands in the Manual, be changed to read as follows: 'Specifications for the Fractionation of Creosote Oil.'"

(The motion was carried.)

The President:—The Committee has no further conclusions to offer, and is dismissed with the thanks of the Association. They have furnished us with some excellent work.

DISCUSSION ON GRADING OF LUMBER.

(For Report, see pp. 873-884.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON GRADING OF LUMBER.

L. C. Fritch. Dr. Hermann von Schrenk.

The President:—The next committee is the Special Committee on Grading of Lumber, Dr. Hermann von Schrenk, Chairman. We will hear from Dr. von Schrenk.

Dr. Hermann von Schrenk (Consulting Timber Engineer):—Mr. President and Members, the Special Committee on Grading of Lumber has continued the work this year which was begun last year, reports of which were published in Bulletin 133. The report of the Committee last year, as you will remember, gave a list of grading rules, submitted by various national organizations for various classes of maintenance of way lumber, it being thought if we had a standard specification (with definitions of defects) for maintenance of way lumber, as well as a list of commercially obtainable grades, it would go far towards unifying standards for the purchase of maintenance of way lumber. During the present year the Committee has continued its efforts with various organizations and presents in its report this year specifications for the grading of cypress. There are still two or three organizations which have not formulated their reports, and it is hoped that the work of the Committee will be brought to a conclusion during the coming year.

In the recommendation as made in this report, the Committee wishes to call your attention to the fact that they have this year very carefully gone over the rules, as submitted last year, and have endeavored to bring them, as far as they could, into harmony with the rules and specifications already adopted, as printed in the Manual. In order to avoid reprinting the entire report of last year, which was rather bulky, they have simply called attention, in the paragraphs at the bottom of page 873, to the changes in the Bulletin as submitted last year, in order to make it conform to the recommendations already in the Manual; and we wish at this time to recommend the adoption of the rules as submitted last year, with the corrections as indicated in the present report, with this change. At the time the report for 1912 was submitted, it was thought that it would probably be printed sufficiently far in advance of the meeting of the convention to give the members a chance to criticise the rules submitted.

Owing to the fact that the report has only been out a short time, I will take it upon myself, as Chairman of the Committee, trusting that the other members will agree, to withdraw recommendation 6, and move that the other rules as submitted last year be adopted at this time.

The President:—The Chair will suggest, gentlemen, that these previous appendices, beginning with A, Classification and Grading Rules for Douglas Fir, be acted upon by the Association in bulk; that is, each appendix by itself, as there has been ample opportunity for the members to make any notes of criticisms they desire to bring forward. Each appendix therefore will be taken up as a whole, and the Association members are asked to criticise it. If no criticisms are offered, or no amendments are made, you will be asked to pass the appendices one by one. Is the Association willing to have that action taken?

(On vote, the suggestion of the President was carried.)

The President:—Each appendix will, therefore, be read by title and a vote will be requested.

The Secretary:—"(Appendix A) Classification and Grading Rules for Douglas Fir."

Dr. von Schrenk:—I move that the Grading Rules for Douglas Fir, printed in Appendix A of Bulletin 133, with the corrections submitted in this year's report, as indicated in paragraph 1, be adopted.

(The motion was carried.)

The Secretary:—"(Appendix B) Classification, Grading and Dressing Rules for Northern Pine, including White and Norway Pine and Hemlock."

Dr. von Schrenk:—I move that the Classification Rules for Northern Pine, including White and Norway Pine and Hemlock, as given in Appendix B, of Bulletin 133, subject to corrections as given in paragraph 3 of this year's report, be adopted.

(The motion was carried.)

The Secretary:—"(Appendix C) Classification, Grading and Dressing Rules for Southern Yellow Pine."

Dr. von Schrenk:—I move you that the Classification Rules for Southern Pine, as given in Appendix C, Bulletin 133, subject to the corrections as indicated in paragraph 4 of this year's report, be adopted.

(The motion was carried.)

The Secretary:—"(Appendix D) Standard Specifications for Construction Oak Timbers."

Mr. L. C. Fritch (Chicago Great Western):—I would like to ask the Committee if this work is the result of a joint conference with the lumber associations.

Dr. von Schrenk:—Yes, sir; it is the result of about four years' work. I move the adoption of Appendix D, Standard Specifications for Construction Oak Timbers, as printed in Bulletin 133, subject to corrections in paragraph 5 of this year's report.

(The motion was carried.)

Dr. von Schrenk:—Appendix E, as given in Bulletin 144, is submitted as information only, and no action is necessary.

The President:—The Committee is dismissed with the thanks of the Association.

DISCUSSION ON BUILDINGS.

(For Report, see pp. 885-899.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON BUILDINGS.

MAURICE COBURN.

The President:—The next report is that of the Committee on Buildings, of which Mr. Maurice Coburn is Chairman. Mr. Coburn will make the opening statement.

Mr. Maurice Coburn (Vandalia):—The Committee has not presented any conclusions this year and our report is presented as information.

The Committee has endeavored to add to the work of the previous year in connection with roofing. We have found a few errors in the technical discussions, which we have endeavored to correct, referring to the pages in the report as published last year. These are not of any great importance. Perhaps the one about water-gas tar is as important as any.

We have tried to get some further information, as suggested at the convention last year, about the asphalt-built-up roofs, but did not succeed in getting anything definite. We also had in mind an endeavor to get a specification for coal-tar pitch for built-up roofing, but we did not succeed in getting that. We do not know whether we are going to be able to get one that is going to be of any value.

We have discussed the asphalt-asbestos built-up roof, and have also added some information about gutters and flashings. We hope during the coming year to fill out this information and complete the work on roofings, presenting particularly the principles which should govern in the design of flashing. The Committee has also done a good deal of work in connection with freight house floors, but we decided that it was not yet wise to present what we have.

We also wish to call attention to the death of Mr. Metcalf, who has been for a good many years one of the most valuable members of the Committee, a man whom we all learned to thoroughly respect. We feel his loss very much.

The President:—Do any members wish to make any remarks on the report of this Committee? If not, they are dismissed with the thanks of the Association.

DISCUSSION ON SIGNS, FENCES AND CROSSINGS.

(For Report, see pp. 900-904.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON SIGNS, FENCES AND CROSSINGS.

C. H. STEIN.

The President:—We will call on the Committee on Signs, Fences and Crossings, Mr. C. H. Stein, Chairman.

I would like to announce that we are very desirous of having lots of good discussion, and I hope the members will feel free to get up and criticize the report as much as they wish. Mr. Stein will make the opening statement.

Mr. C. H. Stein (Central Railroad of New Jersey):—Mr. Chairman, I wish to state, in briefly reviewing the report of the Committee on Signs, Fences and Crossings, that it is distinctly a progress report this year. The first subject assigned was to continue the investigation of ways and means for securing a proper quality of fence wire to resist corrosion and secure durability. This subject has been under discussion and consideration for the past three or four years and a great amount of data has been secured, particularly during the past year. Practical investigations have been conducted by a member of the Committee, and there is also a series of investigations in progress on the part of the Committee of the American Society for Testing Materials. We do not feel that at this time these investigations and experiments have reached a point where we can definitely come to a conclusion; hence the matter should be continued for another year at least, and we believe that at its expiration we will be in a position to announce something to the Association upon which it can take action. We have received the co-operation of the large wire manufacturers, and that has helped us very much in the investigations that we have made. At the present time there are four processes of galvanizing wire under investigation. One is the galvanizing after weaving, the other the ordinary dip process, the third the special galvanized, and the fourth the sherardized. As stated in the Bulletin, the galvanizing after weaving and the special galvanized appear, at this writing, to be giving the best results. The investigation and observation of these wires are still in progress and we will probably learn something about it during the course of this year.

The second instruction was to report on the relative advantages and disadvantages of the different kinds of fence posts. Letters of inquiry were submitted to the various railways and we discovered that very few experiments have been made, so far as the knowledge of the Committee went, from information received, in regard to the use of concrete or other styles of posts than wood. I believe there

are about nine roads that have been making tests of concrete posts, but not for a sufficiently long time to enable them to give us sufficient information on the subject. We propose to look into the matter further, and we think with the groundwork that we have done that we will be enabled to develop some facts during this year that will be of some interest to the Association.

I think two years ago the Committee was directed to report on the best form of track construction and flangeways at street crossings in paved streets. The Committee made certain recommendations in regard to this subject, but it was found after these recommendations were made that the processes they had recommended had not been actually tried out in practice. The Committee has been investigating along these lines, but because of the fact that no actual experimentation had been made it was found difficult to recommend anything, or to prepare plans, as the Board of Direction suggested, to show just what the Committee was endeavoring to arrive at. Since that time, however, the Committee has speculated upon this subject and we have prepared certain tentative plans, and we are negotiating with the steel manufacturers now, and it is thought that during the course of this year the Committee will be able to arrange with the steel manufacturers to roll a few of the rolled fillers that were proposed for flangeways through street crossings and try them out in actual practice. This, it is thought, will be a distinct move in the line of progress on this subject.

There is one other matter that forcibly presented itself to the Committee during this year, and that is that there was a growing demand for uniformity in the styles of signs for all railway purposes, not only for the information of the public, but for that of the railway employe as well. The Committee conducted some little investigation along these lines and felt that, preliminary to actual injunctions from the Board of Direction, that it ought to do something so that if it were seen fit in the wisdom of the Board of Direction to assign this subject to them, that they would have a foundation to work upon and the Committee proposes to recommend that the Board of Direction assign this subject to it for consideration and discussion and possible conclusions during the next year.

I want to state in connection with this subject that during the past year, more particularly than ever before, the public utility commissions of the various States are taking some notice of this subject. A few months ago I happened to be summoned before the Board of Public Utility Commissioners of the State of New Jersey in reference to it, and it was their wish at that meeting to direct us to adopt a certain style of sign for railway crossings. I believed at the time that perhaps other boards of public utility commissioners and State Commissions of various kinds would perhaps take up the suggestion, if they have not already done so, from the action taken in New Jersey, and I thought this, perhaps, was a propitious time

for the Association, through its Committee, to discuss this subject and I told the Commissioners of the State of New Jersey that the Committee was already giving some consideration to this matter and was going to suggest it to the Association at its next meeting, which is the present one.

I have learned only recently that the commissioners of several other States have actually taken up this subject and in one instance, I believe, have actually directed the style of crossing sign that the railroads of that particular State should adopt. Now, it is our opinion that it is highly inexpedient that the boards of public utility commisioners and the railway commissions of the various States should direct any special design of sign until such time as we have given some thought and some study to this subject.

Therefore, the Committee wishes to present the matter to the Association as a live topic for consideration, and we believe that it would be well for us in this respect, as much as in other of our operations, to have uniformity, so that individuals, when traveling from the Atlantic to the Pacific or from the Northern States to the Gulf of Mexico, will see that there is a distinct wording of signs, distinct character of signs, to indicate the purposes for which they are intended. Automobilists, for instance, no matter through what States they travel, may know by the very form of the sign that it represents on all railways a railway crossing. It seems as if these standard signs ought to be adopted from the standpoint of efficiency, utility and economy for the railways, and the Committee, therefore, proposes to recommend that this subject be given it, for its consideration and, therefore, we present the following recommendations:

(1) That the Board of Direction instruct our Committee to endeavor to co-operate with a similar Committee of the American Society for Testing Materials, in reaching conclusion on the subject of a proper quality of fence wire to resist corrosion and secure durability.

(2) That subjects Nos. 2, 3 and 4 assigned last year be reassigned for study and report; that is, the relative advantages and disadvantages of the different kinds of fence posts, the best form of track construction and flangeways at street crossings and paved streets, and the relative advantages and disadvantages of the different kinds of telegraph poles.

(3) That the Board of Direction assign the subject of "uniform railway signs for all purposes as applicable to the public and to railway operation, for study and conclusions."

The President:—Do any of the members wish to make any remarks on the progress report of this Committee? Do any of the members desire to say anything in regard to concrete posts?

If there is no discussion, the report of the Committee will be received and the Committee dismissed with the thanks of the Association.

DISCUSSION ON ECONOMICS OF RAILWAY LOCATION.

(For Report, see pp. 905-906.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON ECONOMICS OF RAILWAY LOCATION.

L. C. FRITCH. A. K. SHURTLEFF.

The President—The next is the Committee on Economics of Railway Location, of which Mr. A. K. Shurtleff is Chairman. Mr. Shurtleff will make the opening statement.

Mr. A. K. Shurtleff (Chicago, Rock Island & Pacific):—Mr. President and Members, the report of this Committee is found in Bulletin 144. The Committee has received one compliment on their report; that was from the Secretary, and he complimented us because of the brevity of the report. There was one most excellent reason for the brevity—we had nothing to say, and we tried not to say it. The Committee feels a little more cheerful than it did last year, as we have received some data from railways which we consider extremely valuable, but it takes time to digest this. I will say that we have a number of members on this Committee who are good workers and willing workers. One or two of them have told me that they were ashamed to tell me how much work they had done and how little it showed in the final results. The Chairman feels the same way about the work that he has done. In digesting this information, it takes an enormous amount of work to accomplish a little for the final results. We trust that next year we will be able to give you, in a substantial form, something in the line of conclusions.

Mr. Begien informs me that the Baltimore & Ohio Railroad is still tabulating the results of those extensive tests they have been making, and this will eventually be given to the Association. I know of nothing further the Committee has to say. We have no apologies because we have not been able to give a report. We have been working, but are unable as yet to give anything that we think should be placed before the Association.

The President:—Does anyone wish to make any remarks?

Mr. L. C. Fritch (Chicago Great Western):—Mr. Chairman, I would like to say, on behalf of the Committee, that in order that the work of this Committee be effective, the membership must make up its mind to furnish them data. The Committtee cannot carry on its work unless the Association furnishes it good, reliable data on which to work.

Mr. Shurtleff:—I want to say in reference to Mr. Fritch's remarks, that after the last annual convention a number of the roads gave us most excellent data for the work, and the Committee feels grateful to those who have furnished that information.

The President:—The Committee will be dismissed with the thanks of the Association.

DISCUSSION ON UNIFORM GENERAL CONTRACT FORMS.

(For Report, see pp. 907-916.)

LIST OF SPEAKERS TAKING PART IN DISCUSSION ON UNIFORM GENERAL CONTRACT FORMS.

C. Frank Allen.
W. G. Atwood.
A. S. Baldwin.
J. B. Berry.
E. C. Brown.
C. Dougherty.
E. A. Frink.
J. E. Greiner.
J. B. Jenkins.
R. G. Kenly.
E. H. Lee.
C. E. Lindsay.
Hunter McDonald.
C. A. Morse.
A. R. Raymer.
J. P. Snow.
W. F. Steffens.
C. H. Stein.
G. D. Swingly.
W. I. Trench.

The President:—The Committee on Uniform General Contract Forms will please come forward. Mr. W. G. Atwood, the Vice-Chairman, will make the statement of the work of this Committee.

Mr. W. G. Atwood (Lake Erie & Western):—This Committee has had meetings, as shown, and in addition the Chairman of the Committee and myself met with the Chairman appointed by the Bridge Builders' Association, who were also working on a general contract form. The contract which they had drawn differed some from the form that we proposed, but after the meeting we were substantially in agreement. The Committee asks the approval of the convention to the general idea which we have set out of having a short agreement which can be used, when desired, in place of letter agreements, which are very common. If we desire a formal contract instead of the acceptance of the proposition by letter, we can use the agreement which we have shown under Form A. In cases of larger work, where more detail is desired, we propose the general condition shown under Form B, the idea being to print the Form A so that the Form B can be bound in it, together with such other clauses as may be desired by the person using the contract. We have, in addition to working with the steel manufacturers, gone over a large number of contract forms in use by various roads, and have also considered the work presented by the Building Committee several years ago. The form, as we have presented it, is unfortunately incomplete, as the Committee has not finally agreed on clauses covering annulment of contract on account of the contractor's fault, annulment of the contract without fault of the contractor, removal of equipment, measurement and approval of work, and final estimate.

The Committee recommends that the work be continued in order that those clauses may be completed. With these clauses we considered that we had covered about all the ground that it is practical to cover in a

general contract of this kind. When applied to specific cases, it will probably be generally necessary to add certain clauses, covering each case.

The President:—Will you read the construction contract as proposed, by paragraphs? We will wait after each paragraph for criticism.

Mr. W. G. Atwood:—"Construction Contract (A—Agreement)—This agreement, made this ..... day of ..... in the year ..... by and between ..... party of the first part, hereinafter called the Contractor, and..... party of the second part, hereinafter called the Company.

"Witnesseth, That, in consideration of the covenants and agreements hereinafter mentioned, to be performed by the parties hereto, and of the payments hereinafter agreed to be made, it is mutually agreed as follows:

"The Contractor shall furnish all the necessary transportation, materials, superintendence, labor and equipment, and shall execute, construct and finish in an expeditious, substantial and workmanlike manner, to the satisfaction and acceptance of the Chief Engineer of the Company .....in accordance with the plans hereto attached or as herein described, and the following general conditions, requirements and specifications, forming part of this contract.

"The work covered by the contract shall be commenced..... ..... and be completed on or before the ..... day of ....., 191.., ...

"This agreement shall inure to the benefit of and be binding upon the legal representatives and successors of the parties respectively.

"In Witness Whereof, The parties hereto have executed this agreement in ..... the day and year first above written.

"Witness: ....."

Mr. E. C. Brown (Carnegie Steel Company):—Is it not unusual to nominate the Contractor as party of the first part in agreements with the railroads.

Mr. W. G. Atwood:—I would say that the practice is not at all uniform. We had under consideration, I think, probably fifty contract forms, and it was done about an equal number of times in each way. It is really a matter that the Committee did not consider of any very great importance. However, the Contractor's signature appears first on the contract, and for that reason it seems that he should be the party of the first part.

Mr. J. P. Snow (Consulting Engineer):—I would like to ask the Committee if they feel it is worth while to say that either the Contractor or the Company is the party of the first part or the party of the second part? Oftentimes an agreement states that such a party "will be hereafter called the contractor" or "the railway," or "the company," or some characteristic name. Is it not better to use some such form than to speak about "party of the first part" and "party of the second part?" It is my preference.

Another thing that occurs to me is that there is nothing apparently in this form that tells what the job is. It seems to me that the first line or the first sentence of an agreement should state what the job is, so that in running over your files you can easily recognize the paper that you are trying to find. Again, it is often necessary to refer to the job in the document, especially in the articles of agreement under B; and my preference is to name the work which is to be done, give it a distinctive title, and say that it will hereafter be called "the work." Then you can refer to it without stringing out the full name. In this way we have "the work," "the contractor" and "the purchaser," whoever it may be—the railway, the company, or some man's name, or the corporation.

Mr. W. G. Atwood:—In reply to Mr. Snow's first criticism I would say that we have found the practice of naming the parties to the contract as the first and second party is very largely a matter of preference. In my own experience I have found one or two attorneys who insisted that it should be in this way. I have also heard of other attorneys who insisted it should be in the way Mr. Snow states. I think that is largely a matter of preference. The Committee thought this was the better way in which to set it out.

In regard to the naming of the work in the first portion of an agreement, that could readily be cared for by a heading. Mr. Snow will find, below the next clause, a blank provided for a description of the work. That changes the order which he suggests, but it is on the first page of the contract.

Prof. C. Frank Allen (Massachusetts Institute of Technology):—Mr. President, in relation to the question of omitting the words "party of the first part" and "party of the second part," it is, of course, a well-recognized fact that in contracts there must be definitely at least two parties. Sometimes the description of one of the parties is somewhat elaborate, and if there is a clear distinction made between those two parties, the contract on the whole is somewhat clearer, and apparently a sharp distinction between the two parties does more clearly establish who the two parties are, if there is an opportunity to put it in this form. It does not impress me as unnecessarily encumbering the contract, but it does, from my standpoint, add somewhat to its clearness.

Mr. Snow:—In reference to the definition of the work, my idea is to have the first sentence simply give a title to the job and say afterwards that "hereafter it will be called the work." The reference, lower down, where the blank is provided for the description of the work, is necessary also, because the work must be defined with a good deal of definition, more than you would want to put into the initial sentence. My idea is that there shall be three distinct terms used for reference all through the agreement, "the work," "the contractor," and the party for whom the work is to be done.

Mr. A. S. Baldwin (Illinois Central):—I agree with Mr. Snow in his suggestion as to the better wording, at the opening clause of the contract. I think, as arranged here, it is a mixture of two forms. It

is rather the older form in which the parties were named as the first and second parties to a contract to take the place, of course, of repetition of names. At the same time undoubtedly that frequently makes one have to refer back to the first part of the contract to refresh one's mind as to who was the first and second party. Subsequent to that the method has become very common of naming one as a Contractor and one as the Railway Company. I would suggest that "party of the first part" and "party of the second part" be removed.

Mr. W. G. Atwood:—I will call the attention of both of the former speakers to the fact that this clause reads, "party of the first part, hereinafter called 'the Contractor,' and blank, party of the second part, hereinafter called 'the Company.'" In the clauses in Form B the two parties to the contract are spoken of in that way.

Mr. A. S. Baldwin:—What is gained by naming them as parties of the first part and second part if not referred to thereafter in the contract by the same terms? If they are referred to as "Contractor" and "the Railway Company," the terms "party of the first part" and "party of the second part" are probably not used again.

Mr. W. G. Atwood:—No; we do not use "party of the first part" and "party of the second part." That is a legal form and some of the lawyers consider it necessary. I don't know personally whether there is any legal objection to withdrawing "party of the first part" and "party of the second part" from this one clause or not, but it doesn't seem to me there is any objection to leaving it there.

Mr. A. S. Baldwin:—I move that in the third line "party of the first part" be eliminated, and in the fourth line "party of the second part" be eliminated.

Mr. A. R. Raymer (Pittsburgh & Lake Erie):—An operating company when making contracts quite frequently includes the name or names of one or more lessee companies, which companies together are called the "first party" or the "second party," etc., as the case may be For this reason the form used by the Committee is preferable

Mr. A. S. Baldwin:—I have seen a great many contracts drawn up in which several parties were combined in one, by referring to such and such parties "hereinafter collectively called so and so," giving them a name that identifies them by name all the way through the contract, which of course answers the same purpose.

Mr. C. H. Stein (Central Railroad of New Jersey):—I want to emphasize the view which is taken by Mr. Raymer. I do not believe we could afford to get up the contracts in any other form. I think there should be some specific designation similar to the one outlined by the Committee. I believe that almost from time immemorial this has been substantially the form in which the contracts have been gotten up, and it frequently happens that the names of contracting parties are so much alike that even we, who are familiar with the general character of the contract but not entirely familiar with the specifications of it, are obliged to be very careful in reading the contract in order to

fully understand what obligations rest upon the respective parties. In my own experience when it has been referred to as "party of the first part" and "party of the second part," I would be obliged to refer to the indication in the preamble to the contract to distinctly understand what particular person was obligated by that particular specification. If names so nearly alike had simply been mentioned it would have been almost impossible to separate them in our minds, and would have made us prone to error in a proper interpretation of the contract. For that reason, I believe, if this paper, as prepared by the Committee, was submitted to the legal departments of the railroads, they would direct that the contract be prepared just in the form that has been arranged for by the Committee. For that reason I think the Committee's report should stand and that the Association should not set aside all the edicts of the legal fraternity and assume to itself the prerogative of how a contract of this kind should be prepared. If the Association thinks there is any question as to the propriety of this character of contract, it had better be submitted to the legal department of some of the railways and get their advice in the matter before the Association arbitrarily says "cut this thing out," or "cut that thing out." This question is of too much importance to be put aside by mere resolutions.

Mr. J. B. Berry (Chicago, Rock Island & Pacific):—I suggest the Committee leave a blank line or two after the description of the parties—there are frequently three or more parties to any contract.

Mr. E. A. Frink (Seaboard Air Line):—I call attention to the last clause, "In witness whereof the parties hereto have executed this agreement in ....., the day and year first above written." It seems to me that date is incorrect, for the reason that a contract is made and completed on the day when the proposition has been accepted, but need not necessarily be signed until some time thereafter, and, therefore, instead of that clause referring to the date first above written, which appears at the head of the contract, it seems to me it should show the date when the contract was actually signed.

Mr. Raymer:—I make one suggestion. The contract follows the usual form in saying, "in accordance with the plans hereto attached." We know this is an idle term, because in most railway contracts it is impossible to attach the plans to the contract, and I think a different form should be used; for instance: "In accordance with the plans identified by the signatures of the parties hereto." This will identify the plans and render unnecessary the words "in accordance with the plans hereto attached."

Mr. W. G. Atwood:—In regard to the criticism of the last clause there is a misprint. The word "in" should be "on." It is my opinion that the contract does not become in force and effective until it is signed. In fact, a contract supersedes by law any prior agreement, verbal or written. The contract is supposed to embody all such agreements, and it does not seem to me the last clause should be changed as suggested.

In regard to Mr. Raymer's criticism, it is, of course, a fact that sometimes the complete plans are not attached to the contract, but that is covered by the words "or as herein described." If the plans are not attached to the contract, the description of the work would necessarily include the plans that would be required to cover the entire work.

Mr. Raymer:—That is true, but there is another point. In work of any magnitude, the detail plans are usually not all completed at the time of the letting of the contract. It may be necessary to make changes in the plans during the progress of the work by agreement with the Contractor. The original plans referred to in the contract should be specifically marked. For this reason it is desirable to have the plans identified by the signatures of the parties to the contract.

To bring the matter before the meeting in proper form, I move that the phraseology now contained in the report of the Committee, "in accordance with the plans hereto attached" or "as herein described," be changed to read as follows: "In accordance with plans identified by the signatures of the parties hereto."

(The motion was lost.)

Mr. W. F. Steffens (Boston & Albany):—Do I understand that there is to be space left for a description of the plans? As the forms now read, the blanks left for necessary or extra writing apply to the beginning and date of completion of the contract. Should there not be a space provided in the contract to identify the plans "as herein described?"

Mr. W. G. Atwood:—It hardly seems to the Committee that in general it is necessary to definitely describe each plan attached. We say, "in accordance with the plans hereto attached." They become part of the contract, but it is a matter of detail arrangement. This contract form probably will not be used very extensively exactly as it is printed, especially as to the spacing of blanks, and I am inclined to think the suggestion of Mr. Steffens is in the line of a detail which it would not be necessary to cover in this general form.

Prof. Allen:—The Railway Company is very likely to have several blank forms of contract; one a short form, with small blanks; and another with larger blanks, and the Railway Company has ample opportunity to print its own forms with such additional blanks as may seem desirable.

Mr. J. B. Jenkins (Baltimore & Ohio):—I suggest that the blank space immediately above, for describing the work to be done, could also be used to describe the plans to be used, and in connection with the motion just lost I would suggest that the contract reads: "As herein described," and these plans could be very readily described as being identified by the signatures of the contracting parties.

Mr. W. G. Atwood:—I would move that the first recommendation of the Committee that the form of construction contract A, as presented by the Committee, be approved.

(The motion was carried.)

The President:—We will now take up the "Construction Contract" B, General Conditions, and it will be read by sections.

(Mr. Atwood read the construction contract by sections.)

"1. Bond. The Contractor agrees, at the time of the execution and delivery of this contract and before the taking effect of the same, to furnish and deliver to the Company a good and sufficient bond of indemnity to the amount of ..... dollars, as security for the faithful performance, by the Contractor, of all the covenants and agreements on the part of the Contractor contained in this contract. The security in such bond of indemnity must be satisfactory and acceptable to the Company.

"This bond shall remain in force and effect in such amount, not greater than that specified, as shall be determined by the Chief Engineer, until the final completion and acceptance of the work."

Mr. C. A. Morse (Santa Fe):—What is intended to be meant by the words "to furnish and deliver to the Company a good and sufficient bond?" Would it not be well to say the Treasurer of the Company in referring to the Railway Company?

Mr. W. G. Atwood:—That practice varies with different companies. In the case of some companies the Chief Engineer controls it, in some cases the Treasury, and in some cases the Legal Department, and in some cases all three.

"2. Contractor's Understanding. It is understood and agreed that the Contractor has, by careful examination, satisfied himself as to the nature and location of the work, the conformation of the ground, the character, quality and quantity of the materials to be encountered, the character of equipment and facilities needed preliminary to and during the prosecution of the work, the general and local conditions, and all other matters which can in any way affect the work under this contract. No verbal agreement or conversation with any officer, agent or employe of the Company, either before or after the execution of this contract, shall affect or modify any of the terms or obligations herein contained.

"3. Intent of Plans and Specifications. All work that may be called for in the specifications and not shown on the plans, or shown on the plans and not called for in the specifications, shall be executed and furnished by the Contractor as if described in both these ways; and should any work or material be required which is not denoted in the specifications or plans, either directly or indirectly, but which is nevertheless necessary for the proper carrying out of the obvious intentions thereof, the Contractor is to understand the same to be implied and required, and shall perform all such work and furnish any such material as fully as if they were particularly delineated or described.

"4. Permits. Permits of a temporary nature necessary for the prosecution of the work shall be secured by the Contractor. Permits for permanent structures or permanent changes in existing facilities shall be secured by the Company.

"5. Protection. Whenever the local conditions, laws or ordinances require, the Contractor shall furnish and maintain, at his own cost and expense, necessary passageways, guard fences and lights and such other facilities and means of protection as may be required."

Mr. C. A. Lindsay (New York Central & Hudson River) :—What is the object of making the distinction between "permits of a temporary nature" and "permits for permanent structures?" It seems to me the line is hazy and might lead to confusion, unless the Committee has some special object in making the distinction.

Mr. W. G. Atwood:—The Committee has already boiled down some clauses bearing on this matter which were much longer. It is intended that the Contractor shall obtain permits, for instance, such as the opening of a street, for the erection of false work or similar temporary work, while it is intended that it shall be the duty of the Company to secure permits in such cases as the permanent change of grade or the position of a sewer or water pipe. Anything that is of a permanent character will be cared for by the Company, and if it is a temporary obstruction it will be the duty of the Contractor to secure the permit.

"6. Rights of Various Interests. Wherever work being done by Company forces or by other Contractors is contiguous to work covered by this contract the respective rights of the various interests involved shall be determined by the Engineer, to secure the completion of the various portions of the work in general harmony.

"7. Consent to Transfer. The Contractor shall not let or transfer this contract or any part thereof (except for the delivery of material) without consent of the Chief Engineer, given in writing. Such consent does not release or relieve the Contractor from any or all of his obligations and liabilities under the contract.

"8. Superintendence. The Contractor shall constantly superintend all the work embraced in this contract in person or by a duly authorized manager acceptable to the Company.

"9. Timely Demand for Points and Instructions The Contractor shall not proceed until he has made timely demand upon the Engineer for, and has received from him, such points and instructions as may be necessary as the work progresses. The work shall be done in strict conformity with such points and instructions.

"10. Report Errors and Discrepancies. If the Contractor, in the course of the work, finds any discrepancy between the plans and the physical conditions of the locality, or any errors in plans or in the layout as given by said points and instructions, it shall be his duty to immediately inform the Engineer. Any work done after such discovery, until verified, will be done at the Contractor's risk.

"11. Preservation of Stakes. The Contractor must carefully preserve bench marks, reference points and stakes, and in case of wilful or careless destruction, he will be charged with the resulting expense and shall be responsible for any mistakes that may be caused by their unnecessary loss or disturbance.

"12. Inspection. All work and materials shall be at all times open to the inspection, acceptance or rejection of the Engineer or his duly authorized representative. The Contractor shall at all times provide reasonable and necessary facilities for such inspection.

"13. Defective Work or Material. Any omission or failure on the part of the Engineer to disapprove or reject any work or material shall not be construed to be an acceptance of any defective work or material. The Contractor shall remove, at his own expense, any work or material condemned by the Engineer, and shall rebuild and replace the same without extra charge, and in default thereof the same shall be done by the Company at the Contractor's expense—or, in case the Chief Engineer should not consider the defect of sufficient importance to require the Contractor to rebuild or replace any imperfect work or material, he shall have power, and is hereby authorized, to make any deduction from the stipulated price that he may deem proper."

Mr. Steffens:—The last sentence is pretty radical, giving the Chief Engineer authority to make any deduction from the stipulated price that he may deem proper for defective work. Unless there is an arbitration clause that is pretty dangerous from the Contractor's standpoint. "As agreed upon by the parties" would be acceptable reading.

Mr. W. G. Atwood:—The Committee felt that perhaps this clause was somewhat radical, not quite in the way Mr. Steffens suggests. It is unusual, I think, in contracts to permit the Chief Engineer to accept work that is not up to specifications. I think all of us have had experiences where we have condemned work and ordered it torn out when we felt that it was not up to specifications, but would perhaps have performed its service. This paragraph leaves an opportunity to use the defective work and allows the Chief Engineer to make a deduction. I do not believe it is practicable to make that a matter of agreement.

(There was no change in the section.)

"14. Insurance. The Contractor shall secure in the name of the Company and for its benefit, policies of fire insurance on such structures and in such amounts as shall be specified by the Chief Engineer not exceeding .....

"15. Indemnity. The Contractor shall indemnify and save harmless the Company for and from all claims, demands, payments suits, actions, recoveries and judgments of every nature and description brought or recovered against it, by reason of any act or omission of the said Contractor, his agents or employes, in the execution of the work by or in consequence of any negligence or carelessness in guarding the same.

"16. Settlement for Wages. Whenever, in the opinion of the Chief Engineer, it may be necessary for the progress of the work to secure to any of the employes of the Contractor any wages which may then be due them, the Company is hereby authorized to pay said employes the amount due them or any lesser amount, and the amount so paid them, as shown by their receipts, shall be deducted from any moneys that may be or become payable to said Contractor."

Prof. Allen:—A question occurs as to this section, whether it is possible that the amount of money that is reserved and payable will in all cases be sufficient to safeguard the Company. A Contractor may do a certain amount of work that proves of very little value to the Company and the workmen who did the work may have a mechanic's lien against the Company; this clause apparently does not sufficiently protect the Company; it has occurred to me that it would be wise to have a provision in the bond looking to matters of that sort. This form of contract is not to be accepted in full at the present time, because it is incomplete in parts,and I make this suggestion to the Committee so that there may be opportunity to take care of this matter if they see fit, either here, or, probably, better, in the bond.

Mr. W. G. Atwood:—I think the bond generally does take care of that.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—I ask the Committee if they intend, in the second line of the clause, the word "employés" to mean also "sub-contractors?"

Mr. W. G. Atwood:—I think that was the intention of the Committee.

"17. Liens. If an established lien be filed against the Contractor for labor or material furnished in the performance of the work, the Company is hereby authorized to pay and discharge the same, if it shall deem best so to do, and to deduct the amount so paid from any moneys which may be or become due and payable to the Contractor."

Mr. Raymer:—The no-liens laws are different in different States. In Pennsylvania it is customary with us to have a "no-lien" clause. The law requires a copy of the contract and some additional information to be filed at the County courthouse; after complying with these requirements the Company is not responsible for liens. These liens sometimes develop after the final payment has been made. I ask the Committee if there is any objection against having a "no-lien" clause included in this contract?

Mr. W. G. Atwood:—It seems to the Committee that the case mentioned by Mr. Raymer and other cases which might occur under various State laws would be special cases that the road using the contract would have to cover in a special clause which they would insert in the contract to meet local conditions. The lien laws do vary quite generally in different States. It might be that in Pennsylvania this clause would have to be materially changed.

"18. Work Adjacent to Railroad. Whenever the work embraced in this contract is near the tracks, structures or buildings of this Company or of other railroads, the Contractor shall use proper care and vigilance to avoid injury to persons or property. The work must be so conducted as not to interfere with the movement of trains or other operations of the railroad; or, if in any case such interference be necessary, the Contractor shall not proceed until he has first obtained specific authority and directions therefor from the proper officer of the Company and has the approval of the Engineer."

Mr. J. E. Greiner (Baltimore & Ohio) :—Suppose there is some other property adjacent to the railway which is not railway property—how are you going to take care of that?

In a highway for instance?

Mr. W. G. Atwood:—I think that is generally covered in another clause—the clause on protection.

"19. Risk. The work in every respect shall be at the risk of the Contractor until finished and accepted, except damage or injury caused directly by Company's agents or employes.

"20. Order and Discipline. The Contractor shall at all times enforce strict discipline and good order among his employés, and any employé of the Contractor who shall appear to be incompetent, disorderly or intemperate, or in any other way disqualified for or unfaithful to the work entrusted to him, shall be discharged immediately on the request of the Engineer, and he shall not again be employed on the work without the Engineer's written consent."

Prof. Allen:—Would it be an advantage to have that read "any employé of the Contractor who shall appear to the Engineer to be incompetent?" That places the responsibility a little more clearly, although the inference from this reading would be to the same effect.

Mr. W. G. Atwood:—The request is to be made by the Engineer according to this clause.

Prof. Allen:—My suggestion would make it a little more definite.

Mr. W. G. Atwood:—"21. Contractor Not to Hire Company's Employés. The Contractor shall not employ or hire any of the Company's employés without the permission of the Engineer."

A Member:—What does that mean?

Mr. W. G. Atwood:—This perhaps covers two things. The Contractor sometimes steals a man from you, very much to your detriment, and I have heard of cases where masonry inspectors, for instance, have been employed as "pumpers" somewhat to the loss of the masonry.

"22. Intoxicating Liquors Prohibited. The Contractor, in so far as his authority extends, shall not permit the sale, distribution or use of any intoxicating liquors upon or adjacent to the work, or allow any such to be brought upon, to or near the line of the railway of the Company.

"23. Cleaning Up. The Contractor shall, as directed by the Engineer, remove from the Company's property and from all public and private property, at his own expense, all temporary structures, rubbish and waste materials resulting from his operations.

"24. Engineer and Chief Engineer Defined. Wherever in this contract the word Engineer is used, it shall be understood as referring to the Chief Engineer of the Company, acting personally or through an assistant duly authorized in writing for such act by the Chief Engineer, and wherever the words Chief Engineer are used it shall be understood as referring to the Chief Engineer in person, and not to any assistant engineer.

"25. Power of Engineer. The Engineer shall have full power to reject or condemn all work or material, which, in his opinion, does not conform to this contract; to direct the application of forces to any portion of the work which, in his judgment, requires it; to order the force increased or diminished, and to decide every question that may arise between the parties relative to the execution of the work.

"26. Adjustment of Dispute. All questions or controversies which may arise between the Contractor and the Company, under or in reference to this contract, shall be subject to the decision of the Chief Engineer, and his decision shall be final and conclusive to both parties.

"27. Order of Completion; Use of Completed Portions. The Contractor shall complete any portion or portions of the work in such order of time as the Engineer may require. The Company shall have the right to take possession of and use any completed or partially completed portions of the work, notwithstanding the time for completing the entire work or such portions may not have expired; but such taking possession and use shall not be deemed an acceptance of the work so taken or used or any part thereof. If such prior use increases the cost of or delays the work, the Contractor will be entitled to such extra compensation, or extension of time, as the Chief Engineer may determine."

Mr. Steffens:—Between sections 26 and 27, it seems that there should be inserted an arbitration clause. This clause makes the Chief Engineer the sole judge of all disputes, whereas an arbitration clause very often saves us from annoying lawsuits.

Mr. W. I. Trench (Baltimore & Ohio):—I have prepared an addition to paragraph 27 to meet a condition I have lately encountered, the case being one in which a Contractor failed to properly locate his plant in the beginning and also failed to remove it in time to avoid delay to the work, and also failed to remove portions of his plant after completion of parts of the work, which seriously delayed a portion of the work to be done by the Company, and to remedy this, I move that an addition be made to paragraph 27 as follows:

"The Contractor shall locate his plant only after careful study of the plans and consultation with the Engineer in charge, so as not to interfere with any work to be performed by the Company during his occupation of the premises; if to facilitate the work temporary location has been permitted, the Contractor shall immediately upon demand of the Engineer remove such plant or portion of plant at his own expense. If the Contractor fails to make said removal, the Company may do it at his expense.

"The Contractor shall remove the plant from finished portions of the work immediately on demand of the Engineer in charge. If he shall fail to make such removal, it may be done by the Company at his expense."

(The above addition was put to vote, but was not adopted.)

Mr. W. G. Atwood:—"28. Changes. The Company shall have the right to make any changes that may be hereafter determined upon, in

the nature or dimensions of the work, either before or after its commencement, and such changes shall in no way affect or void this contract. If such changes diminish the quantity or extent of the work to be done, they shall not, under any circumstances, be construed as constituting, and shall not constitute a claim for damages or for anticipated profits on such work.

"In case quantities in the completed work vary from the quantities shown on the original plans, and provided for in the specifications, then the final payment shall be adjusted on the basis of unit rates specified in this contract.

"NOTE.—First paragraph of section 28 to be used in unit price and force account contracts, i. e., in all contracts not on lump-sum prices. Should be omitted in lump-sum contracts."

The first paragraph of section 28 is intended to be used in unit price contracts, and the second paragraph in lump-sum contracts.

Prof. Allen:—Is it not necessary to have some provision that changes shall not void the contract? Is it not necessary that such a provision shall be inserted, in the case of the lump-sum contract? Is it not as necessary in one case as the other?

Mr. W. G. Atwood:—The Committee will consider the suggestion made by Prof. Allen in regard to that clause and perhaps change it.

Mr. Lindsay:—Section 28 provides for changes in unit price and force account contracts, and provides that in contracts not on those terms—i. e., lump-sum contracts—that the first paragraph should be omitted. How does the Committee propose to take care of changes in lump-sum contracts?

Mr. W. G. Atwood:—Prof. Allen's suggestion was in the same line, and the Committee said they would revise that clause.

"29. Extra Work. No bill or claim for extra work or material shall be allowed or paid unless the doing of such extra work or the furnishing of such extra material shall have been authorized in writing by the Engineer before any part of such work was done or material furnished.

"The price for such work shall be determined by the Chief Engineer, who may either fix a unit price or a lump-sum price, or may, if he so elects, provide that the price shall be determined by the actual cost, to which shall be added ..... per cent. to cover general expense and superintendence, profits, contingencies, use of tools, Contractor's risk and liability. If the Contractor shall perform any work or furnish any material, which is not provided for in this contract, or which was not authorized in writing by the Engineer previous to the doing of the work or the furnishing of material, said Contractor shall receive no compensation for such work or material so furnished, and does hereby release and discharge the Company from any payment therefor.

"If the Contractor shall proceed with such extra work or the furnishing of such extra material after receiving the written authority therefor, as hereinbefore provided, then such work or material, stated in the written authority of the Engineer, shall be covered, governed and con-

trolled by all the terms and provisions of this contract, subject to such prices as may be agreed upon or fixed by the Chief Engineer.

"If the Contractor shall decline or fail to perform such work or furnish such extra material as authorized by the Engineer in writing, as aforesaid, the Company may then arrange for the performance of the work in any manner it may see fit, the same as if this contract had not been executed, and the Contractor shall not interfere with such performance of the work."

Mr. Greiner:—It seems to me that the last part of the second paragraph of section 29 is rather hard on the Contractor. Conditions may arise where the Contractor is compelled to do some work not covered in the contract, in order to protect his work, or something that has not been anticipated, and it may be necessary to do that at a time in advance of notice from the Engineer, and as this paragraph reads he would get no pay for it at all. It seems to me that this part of the paragraph should be worded just a little differently, so that if you have a condition like that, there would not be any injustice done.

Mr. W. G. Atwood:—The Committee has felt that it is necessary to draw this contract as rigidly as it is drawn. The Engineer is an arbitrator and he is supposed to be fair to both parties. The final determination in any case would go to the courts if there was a disagreement, and we feel we have covered this matter of extra work as fairly to both parties as it is possible to do it and protect both parties. An unfair Engineer can, of course, by the enforcement arbitrarily of certain clauses of a contract work great hardships, but I do not believe it is possible to draw a contract, if there is unfairness on either side that will prevent an appeal to the courts.

Mr. Greiner:—The Engineer will have no authority at all on this point. If the Contractor should perform any work, or furnish any material, which was not provided for in the contract, or authorized in writing by the Engineer, previous to the doing of the work, or the furnishing of the material, the Contractor would receive no compensation for such work or material.

The point I am trying to make is that if the Contractor should do work not called for in the contract, that he be paid for it, provided the Engineer shall see fit to authorize it in writing, even after it is started. According to the language used in this section, the Engineer has no right to authorize it, after the work is started, even if it is absolutely necessary.

Mr. Jenkins:—I think the clause as it stands deters the Contractor in some cases from doing necessary extra work in the absence of the Engineer, because he might be afraid he would not get the proper authorization, even after the work is done, and might be afraid that authorization, if issued, would not enable him to collect any money.

Mr. L. C. Fritch (Chicago Great Western):—I think Mr. Greiner's point can be covered if we leave out the words "previous to the doing of the work or the furnishing of material."

Mr. Lindsay:—In the first paragraph, page 51, in line with the suggestion of Mr. Fritch, it would be necessary to eliminate the words "after receiving the written authority therefor."

Mr. W. G. Atwood:—The Committee will accept the amendment.

Mr. G. D. Swingly (Baltimore & Ohio):—The article reads, "Will, however, pay the Contractor for expense of men and teams necessarily retained during the interval of suspension." I would like to know when it would be considered that they were necessarily retained. It seems to me there might be some time fixed after which they will not be paid. That might go on for a long time and might amount to quite an item of expense.

Mr. W. G. Atwood:—I think that is covered by the statement, "provided the Contractor can show that it was not reasonably practicable to move these men and teams to other points at which they can be engaged." The Committee feels that if the Company stops the work temporarily and forces the Contractor to hold his men and equipment on the work, that he ought to be paid for it. In cases where the Contractor cannot use them on other portions of the work, he is entitled to payment until such time as the Company either annuls the contract, or allows the Contractor to proceed with the work.

Mr. Lindsay:—I would like to ask if it is necessary to put in the words "in sections," near the bottom of paragraph 32? Would it not be better to read, "as provided in this contract"?

Mr. A. S. Baldwin:—This clause, as drawn, leaves latitude for a great deal of dispute between the Contractor and the Engineer as to the value or amount of the time that is lost. We have made it a practice to name the price per day that should be charged for teams under those circumstances, and require the Contractor to make it part of his contract, and likewise specify that payment would be for men on monthly time only. This precludes the Contractor from bringing in an excessive claim.

The President:—Mr. Swingly, do you wish to say anything further?

Mr. Swingly:—It is also my idea that the Contractor should be paid for teams which are necessarily idle on account of temporary stoppage of the work; but it seems to me that we might name a time limit, because it might be necessary to hold up the work for a considerable period of time and give the Contractor a very good chance to keep his men and teams there at our expense, and if he did not have other contracts it might be more profitable for him to keep his men and teams there and not try to get them away.

Mr. A. S. Baldwin:—We cover that by naming a price that barely more than lets the Contractor out, with both men and teams. The result is he is after the Engineer to get started just as much as the Engineer is desirous that the Contractor get started.

Mr. W. G. Atwood:—"30. Property and Right of Entry. The Company shall provide the lands upon which the work under this contract is to be done, except that the Contractor shall provide land required for the erection of temporary construction facilities and storage of his material, together with right of access to the same.

"The Contractor shall not enter upon said lands, nor ship any material or equipment, until he has received written notice from the Engineer that he may proceed with said work or any part thereof.

"31. Unavoidable Delays; Extension of Time on Parts of Work. If the Contractor shall be delayed in the performance of the work from any cause, for which the Company is responsible, he shall, upon written application to the Chief Engineer at the time of such delay, be granted such extension of time as the Chief Engineer shall deem equitable and just.

"32. Suspension of Work. The Company may at any time stop the work, or any part thereof, by giving ten (10) days' notice to the Contractor in writing. The work shall be resumed by the Contractor in ten (10) days after the date fixed in the written notice from the Company to the Contractor so to do. The Company shall not be held liable for any damages or anticipated profits on account of the work being stopped, or for any work done during the interval of suspension. It will, however, pay the Contractor for expense of men and teams necessarily retained during the interval of suspension, provided the Contractor can show that it was not reasonably practicable to move these men and teams to other points at which they can be engaged. The Company will further pay the Contractor for time necessarily lost during such suspension at the rate of ..... per cent. per annum on the estimated value of all equipment and fixtures owned by the Contractor and employed on the work which are necessarily idle during such suspension, said rate of ..... per cent. per annum being understood to include depreciation, interest and insurance. But if the work, or any part thereof, shall be stopped by the notice in writing aforesaid, and if the Company does not give notice in writing to the Contractor to resume work at a date within .... of the date fixed in the written notice to suspend, then the Contractor may abandon that portion of the work to suspend and he will be entitled to the estimates and payments for such work so abandoned, as provided in Sections ..... of this contract.

"33. Annulment, Contractor's Fault. Discussed, but not acted upon by the Committee.

"34. Annulment, Without Fault of Contractor. Discussed, but not acted upon by the Committee.

"35. Removal of Equipment in Case of Annulment. Discussed, but not acted upon by the Committee.

"36. Measurement and Approval of Work. Discussed, but not acted upon by the Committee.

"37. Monthly Estimate. So long as the work herein contracted for is prosecuted in accordance with the provisions of this contract, and with such progress as may be satisfactory to the Chief Engineer, the said Chief Engineer will, on or about the first day of each month, make an approximate estimate of the proportionate value of the work done and of material furnished or delivered upon the Company's property at the site of the work, up to and including the last day of the previous month. The amount of said estimate, after deducting ..... per cent. and all

previous payments, shall be due and payable to the Contractor at the office of the Treasurer of the Company on or about the 20th day of the current month.

Mr. E. A. Frink (Seaboard Air Line):—In our work, we have found it saves a good deal of trouble if we require the Contractor, before the first monthly payment, to file with us a schedule of prices for material on specified price contracts and labor and material on lump-sum contracts. Then, in making up the estimates the inspector on the ground makes up an estimate of the work done, makes up a regular form showing his estimate. That is examined by the Contractor, or the Contractor's foreman, and if it is satisfactory, it is signed by both parties and sent to the home office for payment. In that way we avoid all discussion with the Contractor about whether he has or has not been allowed as much as he ought to be allowed.

Mr. Berry:—I would like to ask the Committee whether the members have consulted with their law departments in regard to the bond and contracts.

Mr. W. G. Atwood:—The New York Central Lines' members of the Committee have, and we have found that in various States that various roads' law departments disagree about the same thing. There are undoubtedly things in this contract which some law departments will not approve and will change, but I do not believe it possible to draw a general contract of this kind that will satisfy all law departments. We think that the provisions we have put in this form are legal, and they have been gone over with some lawyers.

Mr. Berry:—The membership on this Committee is scattered throughout the country, and it seems to me that the law departments of the companies with which these members are associated should be consulted in regard to the matter. It is skating on pretty thin ice nowadays unless they are consulted in advance and know all about it; they are a party to it and have got to defend it. Our department always consults them in matters of that kind. Not only that, but my superior officers ask whether I have asked the law department. I would not like to vote, and I think a good many members would not like to vote until they knew the law department had approved the bond and contract.

Mr. E. H. Lee (Chicago & Western Indiana):—In reference to Mr. Berry's remarks, it was the aim of the Committee, in preparing this form, to cover the general conditions. The Committee realizes that it is a matter of impossibility to prepare any general form which will receive the approval of the legal departments of all the roads. In fact, the speaker knows of one case within the last year or two, where the legal representatives of four or five separate Chicago roads were asked for an opinion on identically the same proposition, where there were as many different opinions rendered. The Committee, therefore, feels that the form should be taken as subject at all times to the approval of the legal department of any Company that uses it.

Mr. L. C. Fritch:—I think the Committee is to be congratulated on the excellent form of the contracts which they have given us, especially

the short form, and for more extensive work the long form; but I believe with Mr. Berry, that before we vote on the adoption of this, it ought to be referred back for a legal opinion. There are five clauses which were discussed, but not acted upon by the Committee. It seems to me it would be proper to receive this report as information and have the Committee report finally next year. In the meantime many of us can use this form, but we should get a final report on it for next year.

Mr. Berry:—In the absence of the lawyers, I think I will have to defend them. One of the members of the Committee and I have been on an Engineers' Committee. I found that no two Engineers agreed. However, these same Engineers got together and agreed upon a contract and the work is going forward. I believe the lawyers will finally agree upon a form.

Mr. R. G. Kenly (Minneapolis & St. Louis):—I agree with the proposition made by Mr. Fritch, that these contract forms be referred back to the Committee, that we formulate the specifications, have them printed, send them in the form of a circular letter to every railroad represented in this Association, and ask them to reply with an opinion of their legal department as to the phraseology and legal terms of the specifications. Then let the Committee tabulate them and report to the Association with at least a statement of the majority of the opinions of the various legal departments.

Mr. Curtis Dougherty (Cincinnati, New Orleans & Texas Pacific):—If not out of order, I would like to ask the Committee if they considered any provision to cover the case where the Contractor becomes insolvent and unable to carry the work forward, and the work has to be undertaken by the Company.

Mr. W. G. Atwood:—I would say that that is covered, or will be covered in one of the clauses which the Committee have been considering for annulment; this is one of the clauses which we are considering but are not ready to submit. Among the reasons given for annulment of the contract by the Company is on account of the work not progressing with reasonable speed and the inability of the Contractor to meet his financial obligations.

Mr. L. C. Fritch:—I move that the report of the Committee be received as information and be referred back to the Committee for final report next year.

(The motion was seconded and carried.)

Mr. Jenkins:—I move that the Association thank the Committee for its good work.

(The motion was seconded.)

Mr. Kenly:—I would like to amend that to cover the *active members* of the Committee, and you will have to read the names of those attending the various meetings to find out who were *the active* members.

(The motion was carried.)

The President:—The Committee will be dismissed with the thanks of the Association.

AMENDMENTS.

AMENDMENTS TO COMMITTEE REPORTS.

REFERENCE TO AMENDMENTS MADE TO COMMITTEE REPORTS AT THE THIRTEENTH ANNUAL CONVENTION.

RULES AND ORGANIZATION.

(For Report, see pp. 65-68; discussion, pp. 919-931.)

Amend clause (6) to read as follows:

"(6) After ballast is distributed and the track lifted, the track should be lined and surfaced and the ballast trimmed to conform to standard plans."

Amend clause (7) to read as follows:

"(7) Where track is electrically bonded, ballast must be kept at least one inch below the base of rail. At road crossings, platforms, etc., where this is not practicable, only clean gravel or rock ballast shall be used."

Amend clause (10) to read as follows:

"(10) The renewal of ties shall be started when directed by the .....(Title).....When ties are being renewed, the line and surface shall be corrected, unsuitable material removed and ballast trimmed."

Amend clause (12) to read as follows:

"(12) The.....(Title).....shall frequently inspect ties removed from track to see if any of them have been removed which might have remained in the track with safety until the next inspection."

Amend clause (14) to read as follows:

"(14) Ties must be laid so as to obtain the best bearing. The largest and best ties shall be selected for use at joints. Twisted or badly hewn ties must not be notched, but the bearing must be made true with the adze."

Amend clause (17) to read as follows:

"(17) The bottom of the new rail and the bearing surface of the tie shall be cleaned before the rail is laid."

Amend clause (18) by adding thereto, at the end, the words, "if necessary."

Amend clause (20) and (22) by substituting the term "compromise splices" for the terms "step chairs" and "offset splices."

Amend clause (22) further by striking out the last sentence.

Amend clause (25) to read as follows:

"(25) Rails for curves of 4 degrees and over should be curved before being laid. In curving or straightening rails, a rail bender must be used."

Amend clause (26) to read as follows:

"(26) When picking up joints or other low places, the general level of the track must not be disturbed."

IRON AND STEEL STRUCTURES.

(For Report, see pp. 81-88; discussion, pp. 934-945.)

Amend the "Specifications for Erection of Steel Railway Bridges" by omitting clauses 20 and 21, and renumbering clause 22 to read No. 20.

BALLAST.

(For Report, see pp. 95-300; discussion, pp. 949, 950.)

Add to conclusion on page 97, regarding depth of ballast, the words "gravel or," at the end of the fourth line.

TRACK.

(For Report, see pp. 371-386; discussion, pp. 965-980.)

Amend conclusion 3 on page 374 to read as follows:

"(3) That for all new work, the Committee's recommendations as to lengths of switches and numbers of frogs be adopted."

Amend clause relating to "Stops and Hold-downs," at top of page 379, to read "spring rail," in the first line, instead of "wing rail."

Amend Table I, page 381, third line, under A. B., to read "7 ft." instead of "5 ft."

WATER SERVICE.

(For Report, see pp. 401-428; discussion, pp. 983-988.)

Amend by changing title of Specifications, on page 417, to read as follows: "General Specifications for Steel Water and Oil Tanks."

Amend clauses 1 and 2 to read as follows:

"1. Scope of Specifications. These specifications are intended for steel tanks requiring plates not more than 5/8 in. thick."

Change the numbers of the succeeding clauses, in consequence of consolidating clauses 1 and 2.

Amend the fourth paragraph of clause 3, page 418, to read as follows:

"2. Quality of Metal. The metal in these tanks shall be open-hearth steel. The steel shall conform in physical and chemical properties to the specifications of this Association for steel bridges."

Amend clause 13, page 419, to read as follows:

"12. Tank Support. If the tank is supported on a steel substructure, the latter shall conform to the specifications of this Association for the manufacture and erection of steel bridges, except that allowance shall be made for wind pressure, but not for impact."

ELECTRICITY.

(For Report, see pp. 509-558; discussion, pp. 998-1016.)

Amend clause 10 of the Specifications for Overhead Crossings of Electric Light and Power Lines, page 512, to read as follows:

Substitute the word "possible," in the third line, for the word "practicable."

Amend clause 13, page 513, by omitting the second line in the table, reading, "Exceeding 10,000 volts, etc."

Amend clause 24, page 514, by omitting the words "if such notification is not given, the company crossed shall be furnished with certified reports of shop inspection of material and workmanship made by a properly qualified inspector."

Amend clause 29, pp. 514 and 515, to read as follows:

"29. Insulators, pins and conductor attachments shall be designed to withstand, with the designated factor of safety, the tension in the conductors under the maximum loading."

Amend clause 31, by omitting the words "the most unfavorable condition," on the first and second lines.

Amend clause 32, page 515, to read as follows:

"32. Crossarms shall be designed to withstand the loading specified in paragraph 30, combined with the unbalanced tension of the one wire broken at the pin furthest from the pole."

Amend clause 34, page 515, to read as follows:

"34. The ultimate unit stress divided by the allowable unit stress shall be not less than the following, etc."

Amend the "Note" to read: "The use of treated wooden poles and crossarms is recommended," etc.

Amend clause 45, page 517, by omitting the last sentence, beginning with the word "Pins."

Amend clause 49, page 517, by omitting the words, "of approved species," in the first and second lines.

Amend clause 51, page 517, by omitting the words, "open-hearth," in the first line.

Amend clause 55, page 517, by changing the figures "150." on the first line, to read "180," and the figures "180," on the last line, to read "220."

Amend clause 60, on page 518, by adding the following clause in the second line, after the word "earth (calculated at 30 degrees from the vertical)."

Amend clause 61, page 518, to read as follows:

"61. The top of the concrete foundation, or casing, shall be not less than 6 in. above the surface of the ground, nor less than 1 ft. above extreme high water."

RAIL.

(For Report, see pp. 559-862; discussion, pp. 1017-1038.)

Amend clause 29, page 570, to read as follows:

"29. Payment. Rails accepted will be paid for according to actual weights."

WOOD PRESERVATION.

(For Report, see pp. 863-872; discussion, pp. 1039-1051.)

Amend clause (3), page 864, by substituting the word "beech" for the word "beeches," in the second line; also, by substituting the word "heartwood" for the word "hardwood."

Amend the "Specifications for Creosote Oil," on pp. 865-6, as follows: Transpose the words "including coal gas tar or coke oven tar," in the fourth line of the three specifications to follow the word "tar," in the third line of each specification.

BUILDINGS.

(For Report, see pp. 885-899; discussion, p. 1054.)

Amend diagram on page 863, Fig. 4, top line, to read "Side Flashing," instead of "Head Flashing." Also, change heading on Fig. 2-10 to read "Continuous Head Flashing" instead of "Continuous Foot Flashing."

UNIFORM GENERAL CONTRACT FORMS.

(For Report, see pp. 907-916; discussion, pp. 1059-1076.)

Amend clause 29, pp. 914-5, by omitting the words "previous to the doing of the work or the furnishing of material," in the eighth line of the second paragraph, and the words "after receiving the written authority therefor," in the second line of the third paragraph.

MONOGRAPHS.

THE DESIGN OF RAILWAY BRIDGE ABUTMENTS.

(Bulletin 140.)

By J. H. Prior, Assistant Engineer, Engineering Department Chicago, Milwaukee & St. Paul Railway.

INTRODUCTORY.

Approximations from available statistics show that some $60,000,000 are at present invested in bridge abutments, and as this figure is being increased each year by the value of new work, these structures can be said to have an importance which warrants a fairly extended examination of the present art of their design.

The following paper gives the result of an investigation ordered by Mr. C. F. Loweth, Chief Engineer of the Chicago, Milwaukee & St. Paul Railway, and made by the writer.

A railway bridge abutment is ordinarily a masonry structure, such as is shown in Fig. 1, which gives vertical support to one end of a steel span and gives whatever lateral support to the embankment "A," adjoining, is necessary to prevent the embankment from slipping into the stream.

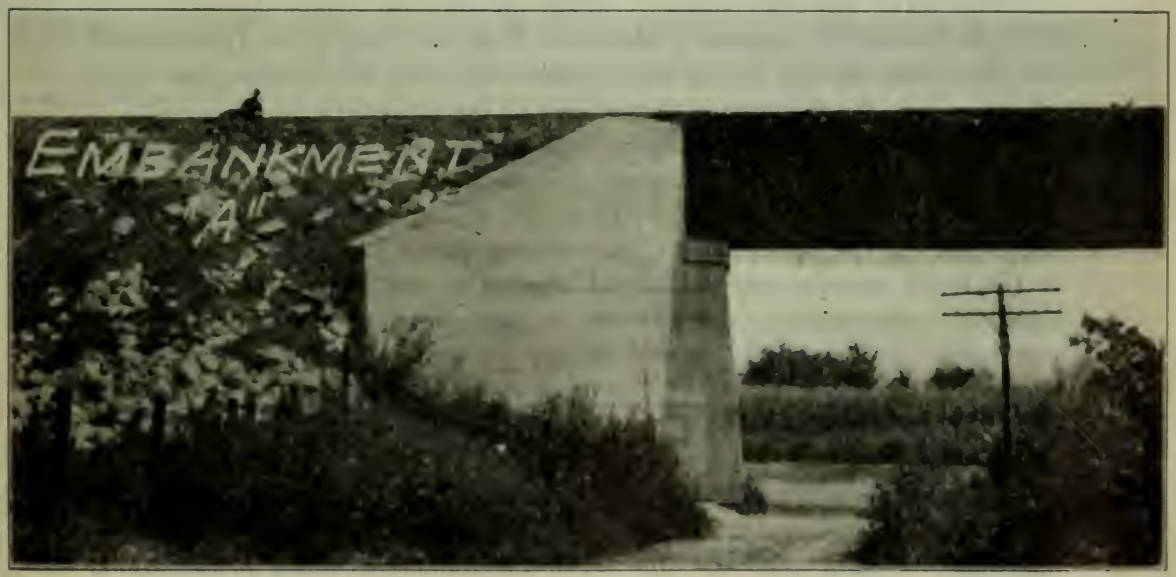


Fig. 1—Plain Concrete Wing Abutment, Type B_2.

The most common type, Fig. 1, has a cross-section similar to that shown in Fig. 2, in which "a" is the bridge seat, consisting of a horizontal surface carrying the steel span; "b" is the back wall which supports the embankment and prevents its spilling forward on the bridge seat; the base "e" of the back wall "b" being made of such width as will make the back wall stable against overturning on account of the lateral pressure "R-1" of the earth; "c" is the main body of the neatwork, and must have sufficient base "f" so that it will also be stable against overturning from the lateral pressure of the earthwork "R-2;" "d" is the footing, which must have a base "g" large enough to carry all the vertical loads, and offset "h" large enough to keep the pressure at the toe of the footing "R-3" within the allowable limit.

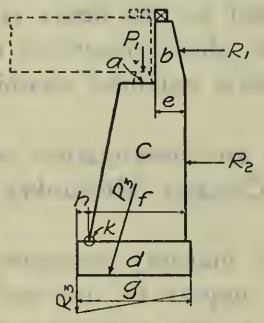
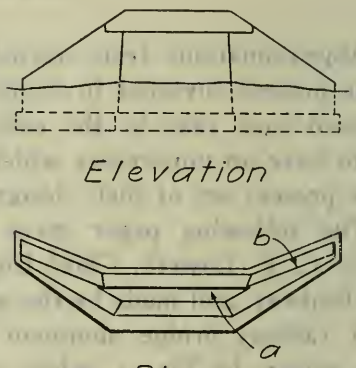


Fig. 2



Wing Abutment

Fig. 3

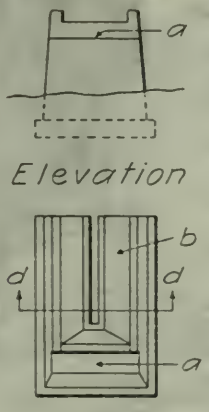
The three principal types of abutments are the wing abutment, Fig. 3; U abutment, Fig. 4; and T abutment, Fig. 5. These three types, which are the oldest as well as the most important, were developed when stone masonry was the only material available to the designer.

In the wing abutment, Fig. 3 and Fig. 1, the span is supported on the bridge seat "a," and the wings "b" keep the embankment from slipping into the stream. In the U abutment, Fig. 4 and Fig. 6, the span is supported on the bridge seat "a," and the wings "b" are made parallel to the track, thus giving the lateral support to the embankment which is required to extend the embankment to the bridge seat. In the T abutment, Fig. 5, the span is carried on the bridge seat "a" and the floor is supported directly back of the bridge seat by the stem "b" of the abutment, which carries the track back to a point where the embankment is of sufficient height to support it.

Some of these older types, which were best adapted to stone masonry, have exerted considerable influence in later designs executed in the newer materials of plain concrete and reinforced concrete, often in situations where the old design was poorly adapted to the newer material.

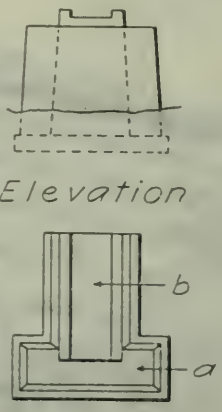
ABUTMENTS BUILT OF STONE MASONRY.

The wing abutment, Fig. 3; U abutment, Fig. 4; and T abutment, Fig. 5, are referred to as type A_1, type A_2, and type A_3, respectively, when constructed of stone masonry. As railway structures, some of these types are rapidly becoming obsolete, but as they are the prototypes of all present designs and exerted considerable influence on later designs executed in different material, they are given some mention.



U-Abutment

Fig. 4



T-Abutment

Fig. 5

The wing abutment of stone masonry, type A_1, is often found to be of such a design that the section of the abutment along the center line of track is about as shown in Fig. 8. This might have been a creditable design in the day in which it was made, but at present it is not much of an exaggeration to say that this cross-section represents everything that an abutment should not be. The batter on the front of this abutment is slight, and the bridge seat is thus set so far forward over the footings that the resultant of the vertical loads and lateral pressure of the earthwork is located so near the front edge of the footings that the pressure on toe is excessive for ordinary foundations. Without any increase of material in the cross-section, this cross-section can be revised to that shown in Fig. 9, with reduction in the toe pressure, as shown in the figures, from 7½ tons to 4.07 tons per square foot, or about 45 per cent reduction. While the cross-section is not increased in area, the change from Fig 8 to Fig. 9 is accompanied by a greater cost, on account of the increase in the length of the span, due to moving bearing from the point P, in Fig. 8, to the point P-2 in Fig. 9. This would amount to an increase in the length of the span of 5 ft. and an additional cost of $250.00, which is only 5 per cent. additional cost for one abutment. Although this increase in the cost of the steelwork incident to changing the outline

of the cross-section is a small percentage, it probably accounts for the nearly vertical front faces of the abutments, and the bridge seats located near the front of the footings in the design of many old abutments, which can be found in every railway office. The cross-section, Fig. 8, is taken from the details of an abutment dated 1887.

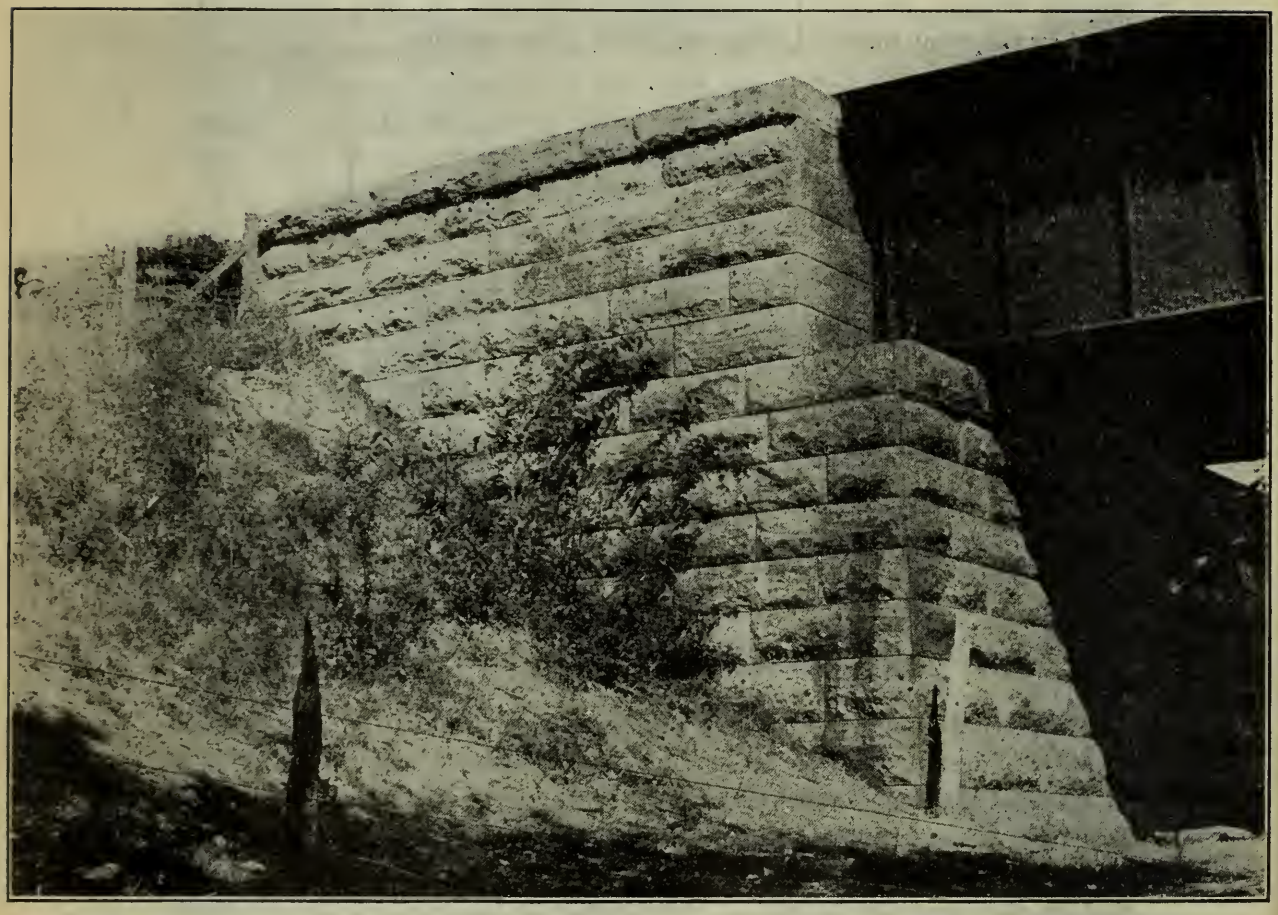


FIG. 6—STONE MASONRY U ABUTMENT, TYPE A_2.

The U abutments of stone masonry, type A_2, Fig. 4 and Fig. 6, have a section as shown in Fig. 10, which is a cross-section at right angles to track along the line "dd" of Fig. 4. In this abutment the side walls "a," which retain the fill "f," are usually built with a base thickness "e" equal to 0.4 of the height "h." For an abutment 14 ft. in width, the backs of the two side walls "a" would intersect at the point "b" when "h" was equal or greater than 17.5 ft. Thus an abutment built of this design would be a solid mass of masonry below the point "b," as shown in Fig. 10. For this reason they show only small economy over the wing and T abutments for heights from 12 ft. to 24 ft., as illustrated in Fig. 11.

In Fig. 11 the cubic yards of masonry in abutments, exclusive of

footings and copings for various heights, are platted as ordinates with the height from the top of footing to bottom of coping as abscissas.*

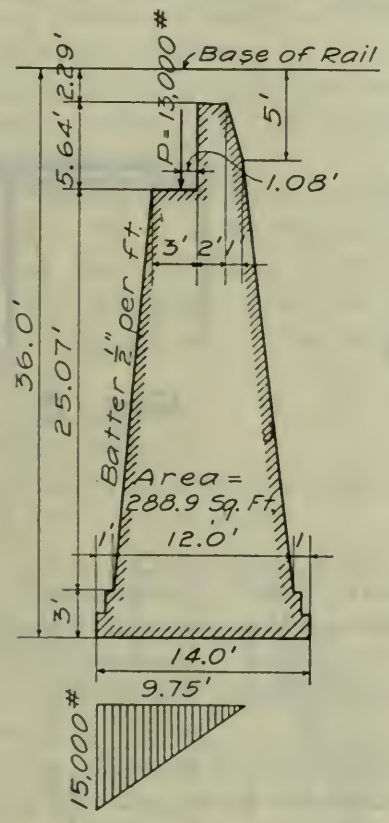


Fig. 8

DEFECTIVE CROSS-SECTION FOR ABUTMENT.

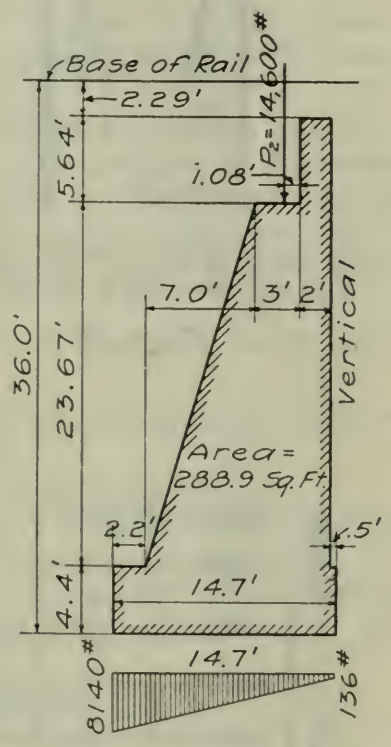


Fig. 9

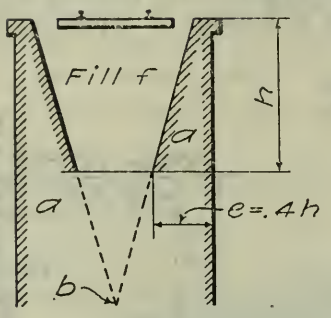
IMPROVED CROSS-SECTION FOR ABUTMENT.

The small economy of the neatwork of U abutments, shown in Fig. 11, is lost if the same slope of embankment of 1½ to 1, which was used in determining the length of the wing walls of the wing abutments, is used to determine the length of the side wall of the U abutment.

The T abutment of stone masonry, type A_3, Fig. 5, has a cross-section at right angles to the track, as shown in Fig. 12. It can be seen from Fig. 12 that the cross-section of the T abutment would resemble very closely the cross-section of a U abutment if the height of the U abutment was much greater than 17.5 ft., and an examination of Fig. 11 will show that there is no great difference in volumes or cost between the T abutment and the other two types.

There was not much uniformity in the design of the stone abutments, and data concerning them are scarce and meager; therefore, the curves showing the volumes of these abutments in Fig. 11 can only be considered approximate.

*Volumes taken from old standards of a western railway company, shown in Baker's Masonry, pp. 357-363, Wiley & Sons. 1905.



Cross section d-d at right-angles to track

Fig. 10

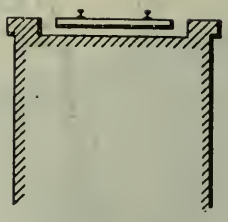


Fig. 12

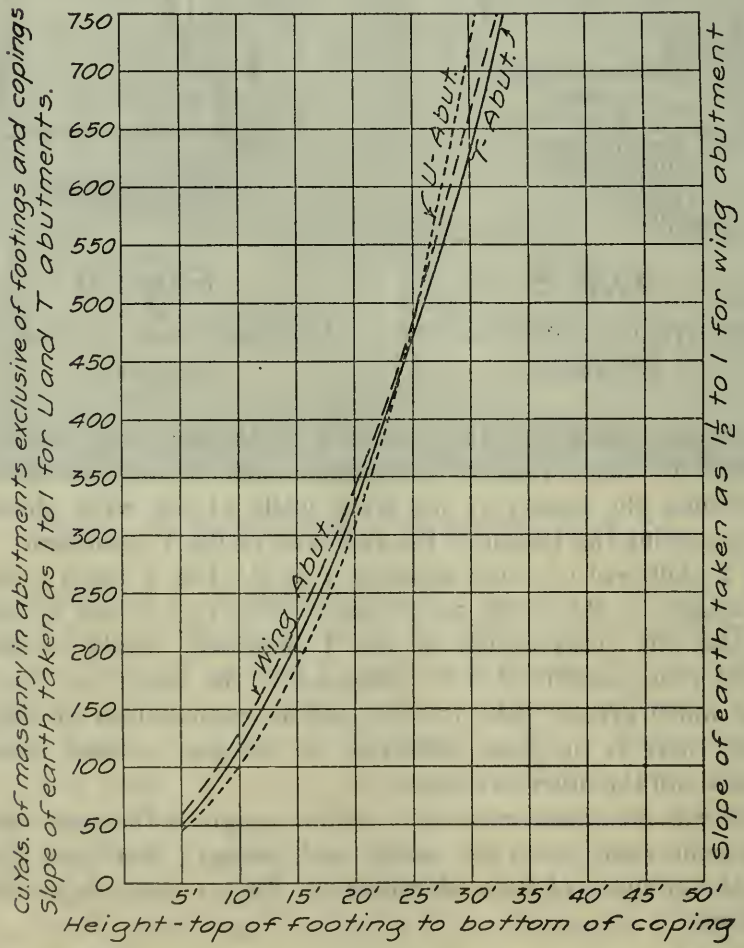


Fig. 11

ABUTMENTS OF CONCRETE, PLAIN AND REINFORCED.

In addition to conforming to the ordinary laws of structural design, there are a number of properties which have an unusual importance in the design of bridge abutments.

Properly designed abutments should have the following properties, which may be called major requirements, because they affect the integrity of the structure:

m_1. The neatwork should be stable against overturning by revolving on the line k, Fig. 2, at the intersection of the front face of the neatwork and footing, and should also be safe against crushing on the same line.

m_2. The abutments should be stable against sliding, either by the neatwork sliding on the footing or the footing sliding upon the foundation bed.

m_3. The pressure of the toe of the footing upon the foundation should not be excessive.

They should have the following properties, among others, which may be called minor requirements:

n_1. The abutments should protect the bank against scour.

n_2. The abutments should prevent the embankment drainage from washing away the shoulder of the bank adjacent to the back wall.

n_3. The abutments should provide a joint which will support the track in an easy and continuous manner from embankment to superstructure.

n_4. The abutment should be easily drained.

As by far the greater number of abutments being built are either of plain or reinforced concrete, the term "Design of Bridge Abutments" at present means the design of bridge abutments in concrete masonry.

All the abutments mentioned in the following, together with the three abutments mentioned in the foregoing paragraphs, have been tabulated in Appendix A for ease in reference.

In order to compare the properties and economy of the various types, it was necessary to assume the same conditions in the design of all types. The more important assumptions which were made for this purpose are as follows:

(1) The height of the abutment is the distance "H" of Fig. 25 from the base of rail to the natural ground.

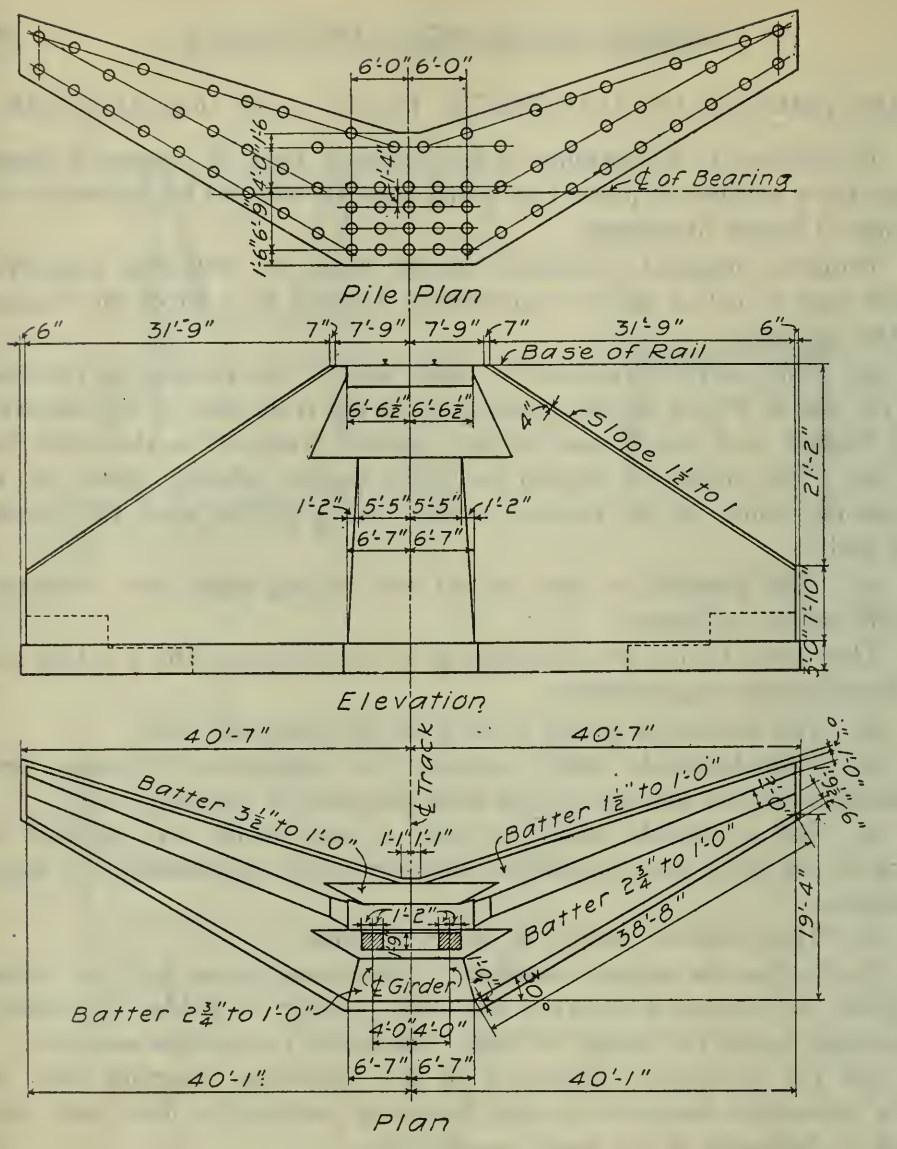
(2) Slope of fill 1½ to 1.

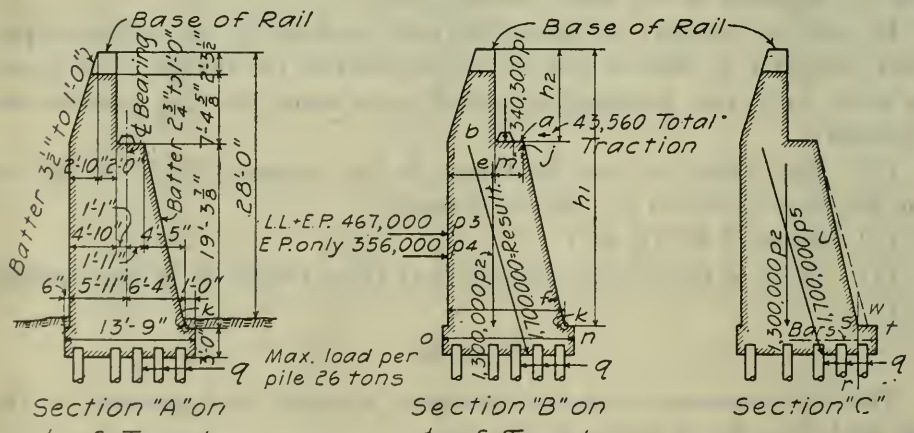
(3) Slope of the natural ground away from stream or bridge opening 4 to 1.

Type B_1.

The plain concrete masonry abutment without reinforcement in the back wall, type B_1, is shown in Fig. 13.

As this abutment is designed without steel reinforcement of any kind, its design is made in a similar manner to the wing abutment of stone masonry, type A_1, previously described. The cross-section of the





Type B, Plain Concrete Wing Abutment with Plain Concrete Backwall

Fig. 13

abutment, marked "section B on center line of track in Fig. 13," is determined about as follows:

The distance "h_2," from the base of rail to the top of the bridge seat "a," is determined by the depth required by the floor, girders and bearings of the superstructure; and in new work the abutment must conform to these dimensions. The dimension "e," which is the width of the back wall at its base, is taken as 4/10 "h_2" if the lateral pressure of the earthwork tending to overturn the back wall is alone considered, or it is taken at 5/10 "h_2" if a slight further provision is made for the overturning action of frost in the bank. The width of the bridge seat "m" is determined by the width required for the superstructure bearings plus whatever distance "j" is required to keep the bearings back far enough from the outer edge of the bridge seat to prevent the outside corner of the bridge seat from being sheared off in a diagonal direction.

The position of the ground line and the character of the foundation determine the distance "h_1" from the base of rail to top of footing. If the base of the neatwork "f" is made 4/10 of the distance "h_1," the neatwork is stable against overturning or crushing on the line "k," at the lower front edge of the neatwork. The dimension "f" together with the width of bridge seat "m" and thickness of back wall "e" having been determined, we have the choice of setting the bridge seat and back wall vertically over the rear edge of the footing, as shown in Fig. 13 and by the full lines in Fig. 14, or we can locate the bridge seat and back wall nearer the front of the footing, as shown by the dotted lines in Fig. 14, and thus decrease the length of our superstructure at the expense of an increased bearing on the toe of the foundation.

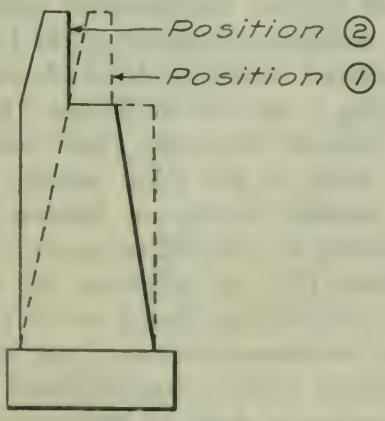


Fig. 14

The design of the cross-section entirely without reinforcement leaves this type with two important defects. If the outline of the neatwork, marked position 1, and shown by dotted lines in Fig. 14, gives excessive toe pressure, it is desirable to alter the outline of the cross-section to about that of position 2, shown by full lines in Fig. 14. The object in

changing the outline from position 1 to position 2 is to move the point of application of the forces "p_1" and "p_2," Fig. 13, toward the back of the footing, thus moving the resultant "p_5" also toward the back of the footing, and consequently decreasing the pressure on the front edge of the neatwork and the toe of the foundation. But in an abutment, in which the back wall contains no reinforcement, these forces cannot be moved toward the back of the footing by any great amount on account of the large width "e" of the base of the back wall, which is made from .4 to .5 of "h_2."

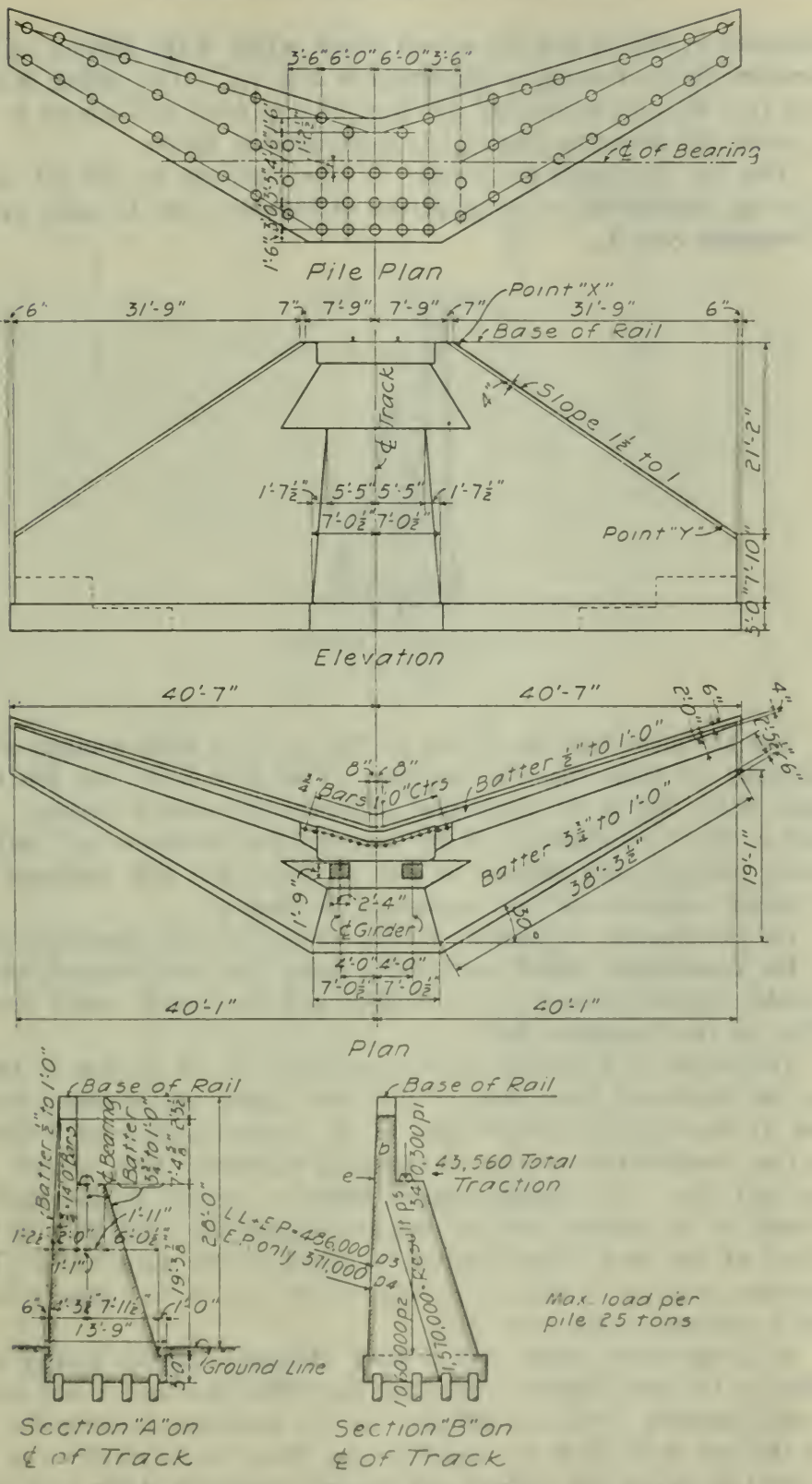
Fig. 15 shows an abutment, type B_2, of the same height as the abutment, type B_1, Fig. 13, except that the back wall "b" is reinforced against overturning by some ¾ in. by 14 ft. bars. The addition of these bars permits the base "e" of the back wall "b" to be made 2 ft. 5 in. in width instead of 4 ft. 10 in. in width in type B_1. This decreased width of back wall base permits the point of application of the resultant of the loads "p_1" and "p_2" to be moved an average distance of 6 in. toward the back of the footings, by this means decreasing the pressure on the toe of the footings from 3.7 tons to 3.2 tons pressure on natural foundation, at no additional cost in the abutment, and at an additional cost of only $100 in the superstructure.

The other defect is due to the absence of bars in the foundation of type B_1 and is shown by a comparison of the cross-section of the abutment marked "Section B on center line of track" in Fig. 13, with the section "C" in the same figure.

In Section "B" the maximum load comes on the piles located nearest to the toe of the footing. The load on each pile is determined by the total number of piles and by their location with reference to the resultant of all the loads on the abutment, marked "p_5" in Fig. 13. If foundation conditions were encountered which made it desirable to decrease the maximum bearing on piles of 26 tons in Section "B," or to decrease the total number of piles without increasing their loading, it could be accomplished by moving some of the piles, marked "q" in Section "B," forward to about the position shown on Section "C," thus increasing the projection of the footing beyond the neatwork from 1 foot in Section "B" to 2 feet in Section "C." To reinforce the cantilever beam "s-t" against bending, some bars must be placed at the bottom of the footing, crossing the section of maximum moment "r-s;" but if it is required to build the entire abutment without reinforcement, these bars cannot be used, and instead the neatwork must be increased by changing the face of the neatwork from the line "s-u" to the line "v-w," thereby increasing the volume of the neatwork by 16 yards and that of the footing by 5 yards.

Type B_2.

Abutment type B_2, Figs. 15 and 15_a, is similar to abutment type B_1, Fig. 13, except that the two defects just described are remedied. The defect first mentioned, which is the absence of bars in the back wall, is

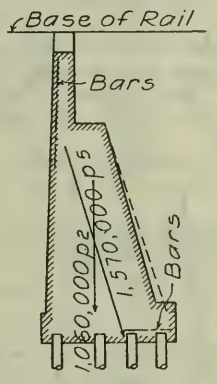


Type B2 Plain Concrete Wing Abutment with Reinforced Concrete Backwall

Fig 15

eliminated in Fig. 15 and the second defect, which is the absence of reinforcement in the footing, is eliminated in Fig. 15_a. The saving in abutment type B_2, due to altering the cross-section from that shown in Fig. 15 to the one shown in Fig. 15_a, is approximately $90.00.

The two abutments are similar in other respects so that all of the following descriptions of the properties of abutment type B_2 apply equally to abutment type B_1.



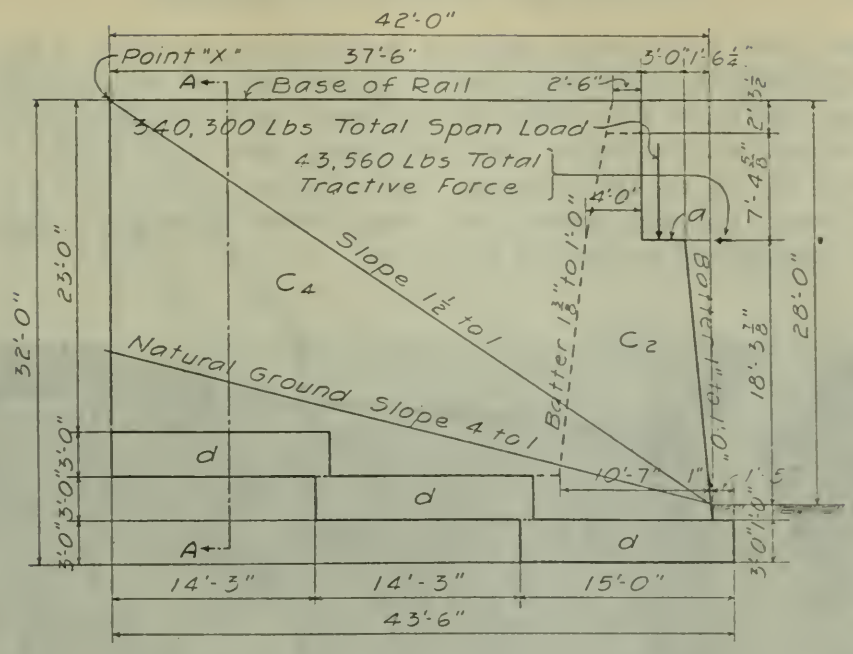
Abutment Type B_2
Fig. 15a

The abutment type B_2, shown in Fig. 15, is a wing abutment built practically of plain concrete masonry. This type is by far the most widely used, and is an economical abutment for certain heights. The position of the resultant of all the loads on the abutment "p_5," and the loading per pile, also entered in Fig. 15, show that this abutment has the major requirements "m_1" mentioned on page 9.

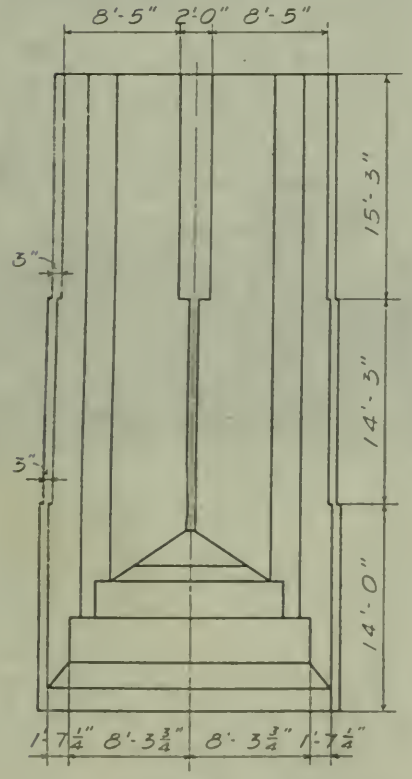
An examination of Section B also shows that the abutment satisfies the requirement called "m_2," which states that the neatwork should be stable against sliding on the footing, and the footing stable against sliding on the foundation bed.

The angle of inclination of the resultant "p_5" in Section B shows that the horizontal component of the force which the abutment exerts upon its foundation is 31 per cent. of the vertical component. This is less than coefficient of friction of nearly all foundation beds, except, perhaps, wet clay. The stability against sliding is assisted by the back fill in front of the abutment and the pressure against the wing walls of that portion of the bank which extends in front of the wing walls. This abutment conforms to the minor requirement "n_1" to "n_4" page 9 in as large a measure as any other type.

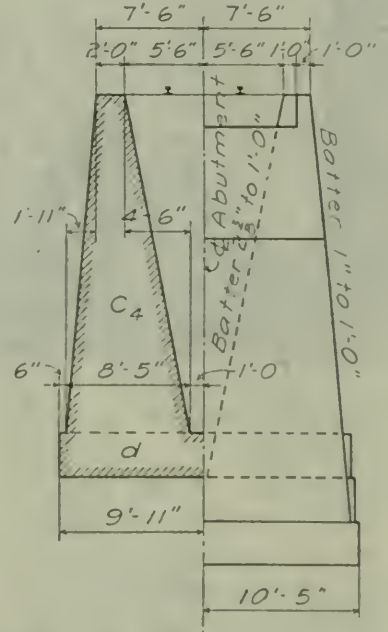
It is sometimes stated that a wing abutment affords greater protection to the bank against scour than any other type, but it can hardly be said that the protection afforded by the abutment is complete. If only the end of the bank be considered, as shown in the elevation of the abutment in Fig. 15, the protection is complete, especially if the wing walls are of such a length as to bring the top of the wing wall close to the



Side Elevation



Plan



Half Section "A - A"

Half Front Elevation

Type B_3 - Plain Concrete "U" Abutment - Filled

Fig 17

ground. But, if the side of the bank be considered, as shown in Fig. 18, it will often be found necessary to protect the toe of the bank by rip-rap similar to that shown in the figure, and without this rip-rap the protection afforded by the heavy wing walls at the end of the bank is not far enough extended. Fig. 19 shows the situation where a bank which has been washed away from behind a wing abutment has been replaced and protected with rip-rap.

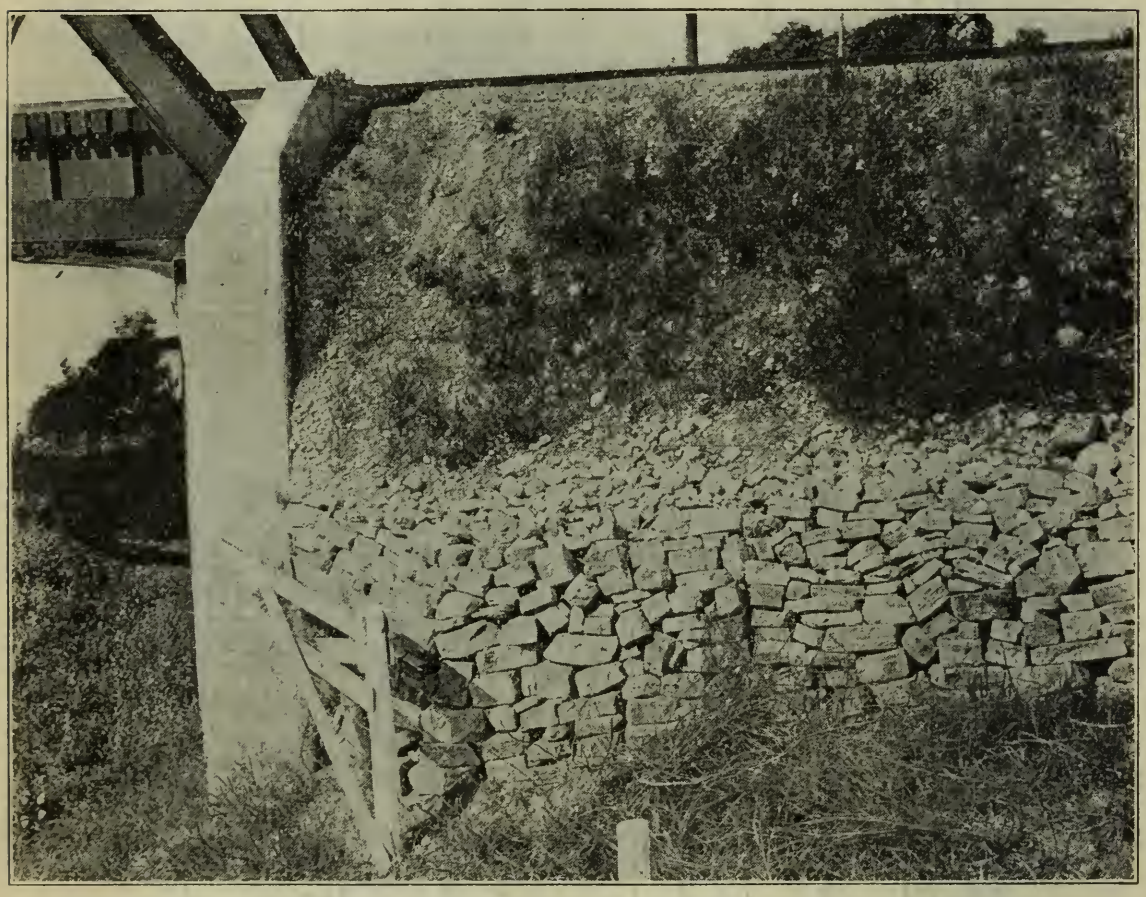


FIG. 18—TOE OF EMBANKMENT PROTECTED BY RIP-RAP.

Abutments of this type do not cause the drainage water to wash away the corner of the bank adjacent to the back wall at "x" on Fig. 15, but at the lower point "y" on the bank, Fig. 15, where the amount of the drainage water is greater, there seems to be a tendency to wash the portion of the bank adjacent to the end of the wing wall, and, therefore, this point is often found protected by loose rip-rap, as shown in Fig. 20.

It is possible with this abutment to provide a joint between the bank and superstructure which will support the track in as easy and continuous a manner as any other abutment, especially if a ballasted floor is used, as shown in Fig. 21.

FIG. 19—EMBANKMENT PROTECTED BY RIP-RAP AFTER WASHOUT.

FIG. 21—TRACK RAILS AND TIES CONTINUED OVER BALLAST FLOOR BRIDGE.

FIG. 20—PORTION OF BANK ADJACENT TO THE END OF WINGWALL PROTECTED BY RIP-RAP.

Type B_3.

The U abutment of plain concrete masonry, type B_3, is shown in Fig. 17. This abutment is designed substantially in the same manner as the U abutment of stone masonry, type A_2, page 6, except that the side walls, C_4, are made long enough to provide for an embankment slope of 1½ to 1, as experience shows that the slopes at the end of the embankment cannot be made much steeper than the side slopes of the same embankment.

This lengthening of the side walls C_4 of abutment B_3 to take care of the 1½ to 1 embankment slopes, results in making the neatwork yardage for abutment B_3 greater than for abutment B_2. This difference in yardage in the neatwork is overcome by the lower foundation costs of abutment B_3 so that the total cost of abutment B_3 is somewhat less than abutment B_2 for heights over 23 feet, as shown in Fig. 45.

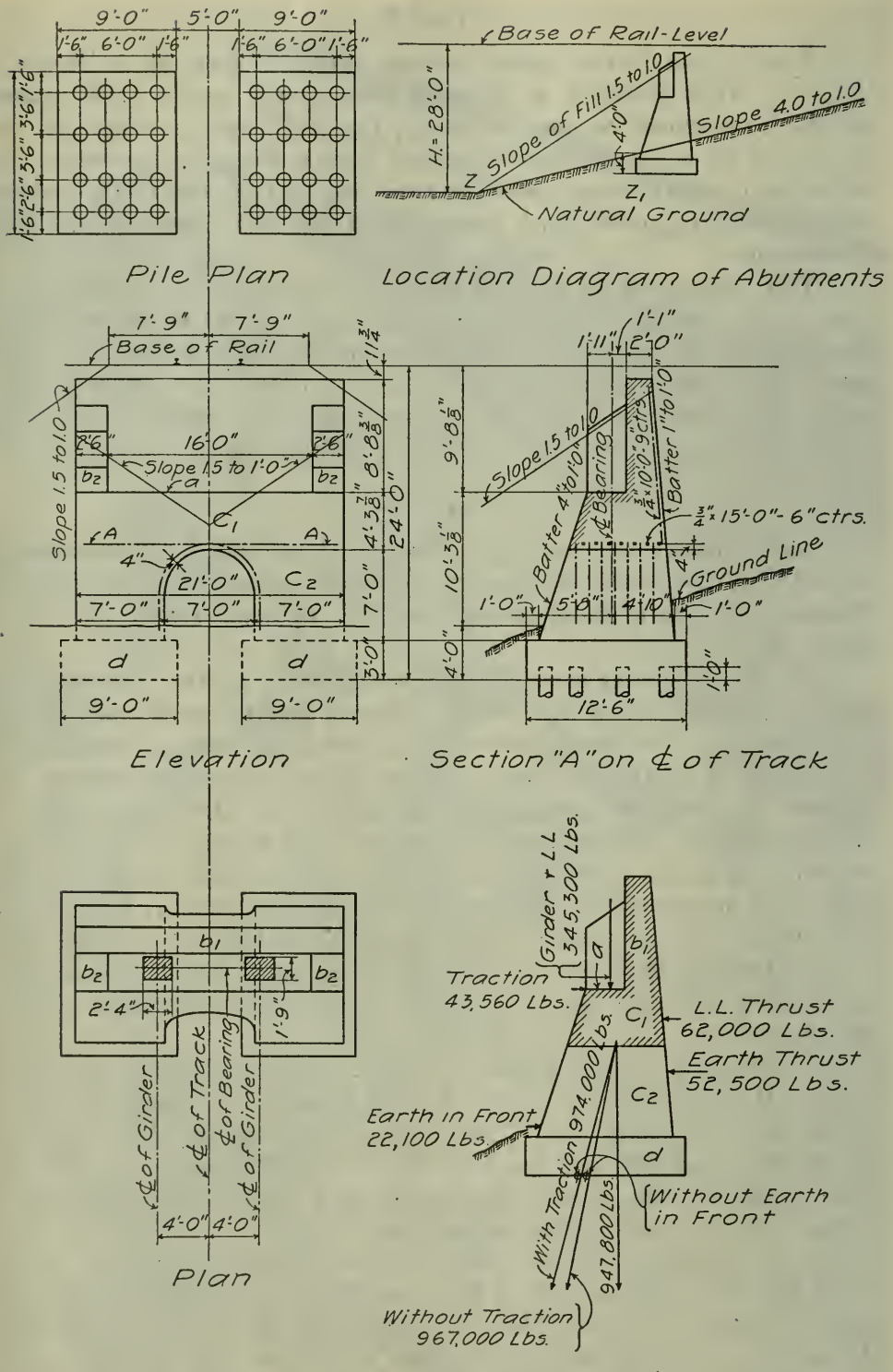
Type B_5.

An examination of Section B, Fig. 15, shows that it is more difficult to make provision in an abutment to resist the lateral forces "p_3" and "p_4" tending to overturn the abutment than it is to take care of the vertical loads "p_1" and "p_2."

The lateral forces are exceeded in magnitude by the vertical forces, but the vertical forces are directly opposed by the equal and opposite reaction on the foundation, whereas no such equal and opposite reaction can be placed on the line "p_3" continued, which shows the direction and location of the lateral pressure of the earthwork. As a consequence it would seem that a considerable economy could be effected in a design in which the lateral forces "p_3" and "p_4" were eliminated or greatly diminished. In abutments B_5, Fig. 22; B_6, Fig. 23; B_7, Fig. 24; and B_8, Fig. 25, little provision is made for resisting the lateral pressure of the earthwork. Instead, provision is made for diminishing the lateral pressure by omitting the wings and allowing the bank to spill around in front of the abutments.

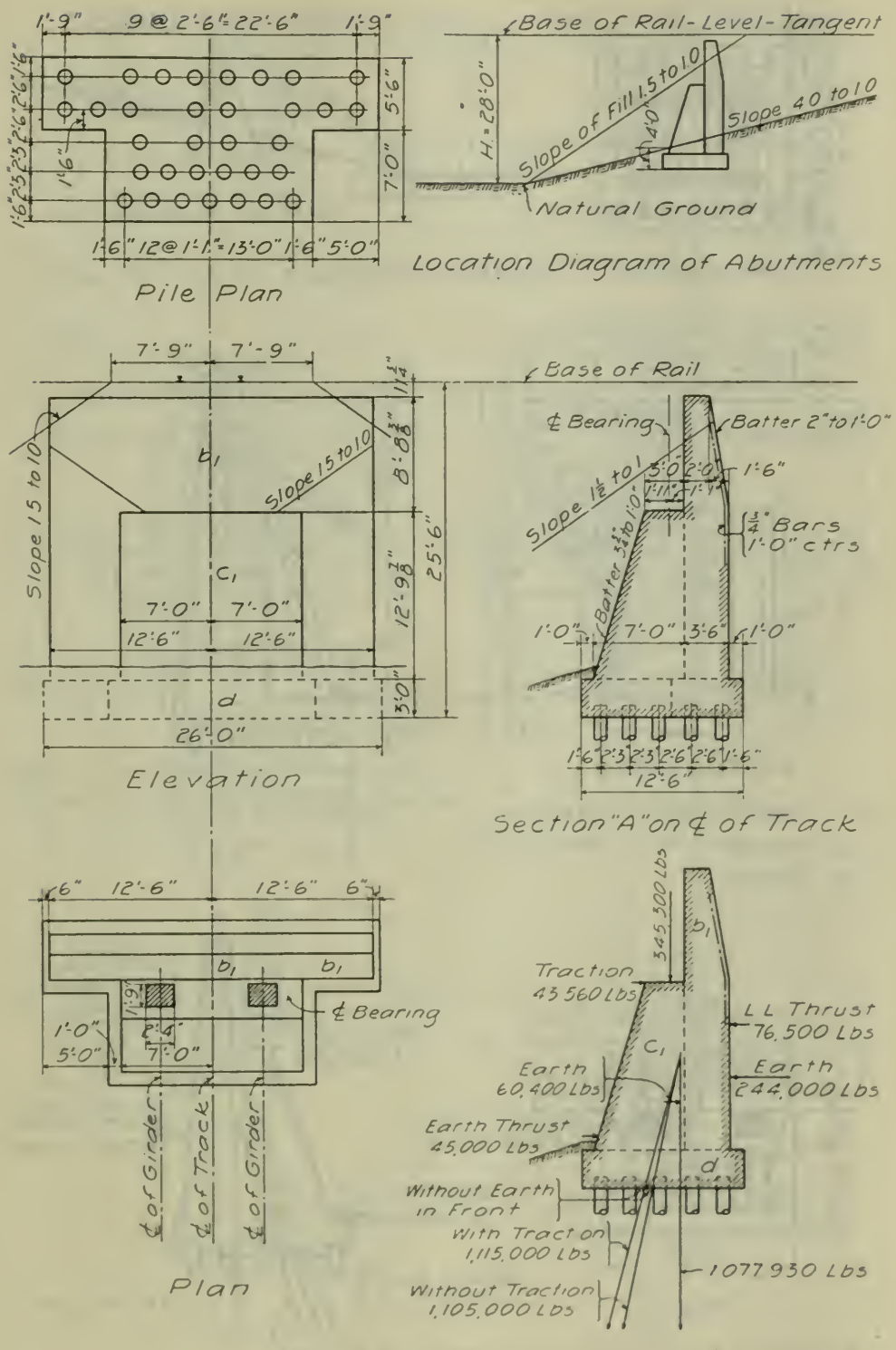
Abutment type B_5, Fig. 22, consists, as shown in the elevation and Section B, of two short piers, which carry a beam "c-1," the top of which forms the bridge seat "a." The earthwork is kept off the bridge seat by the back wall "b_1" and the side walls "b_2." The bank is permitted to run around in front of the abutment to the point "z" where the natural slope of the fill intersects the ground line.

If an abutment type B_5 and an abutment type B_1 were so located as to have their bridge seats in the same position, the abutment B_5 would give a smaller waterway than the abutment type B_1 by the distance from "z" to "z_1" in Fig. 22, to which the fill extends in front of the abutment. In order to get the abutment B_5 on the same basis for comparison as the other abutments, it is necessary to add to the cost of abutment B_5 the cost of extending the superstructure so as to permit the location of the abutment to be moved from "z" to "z_1." As shown in



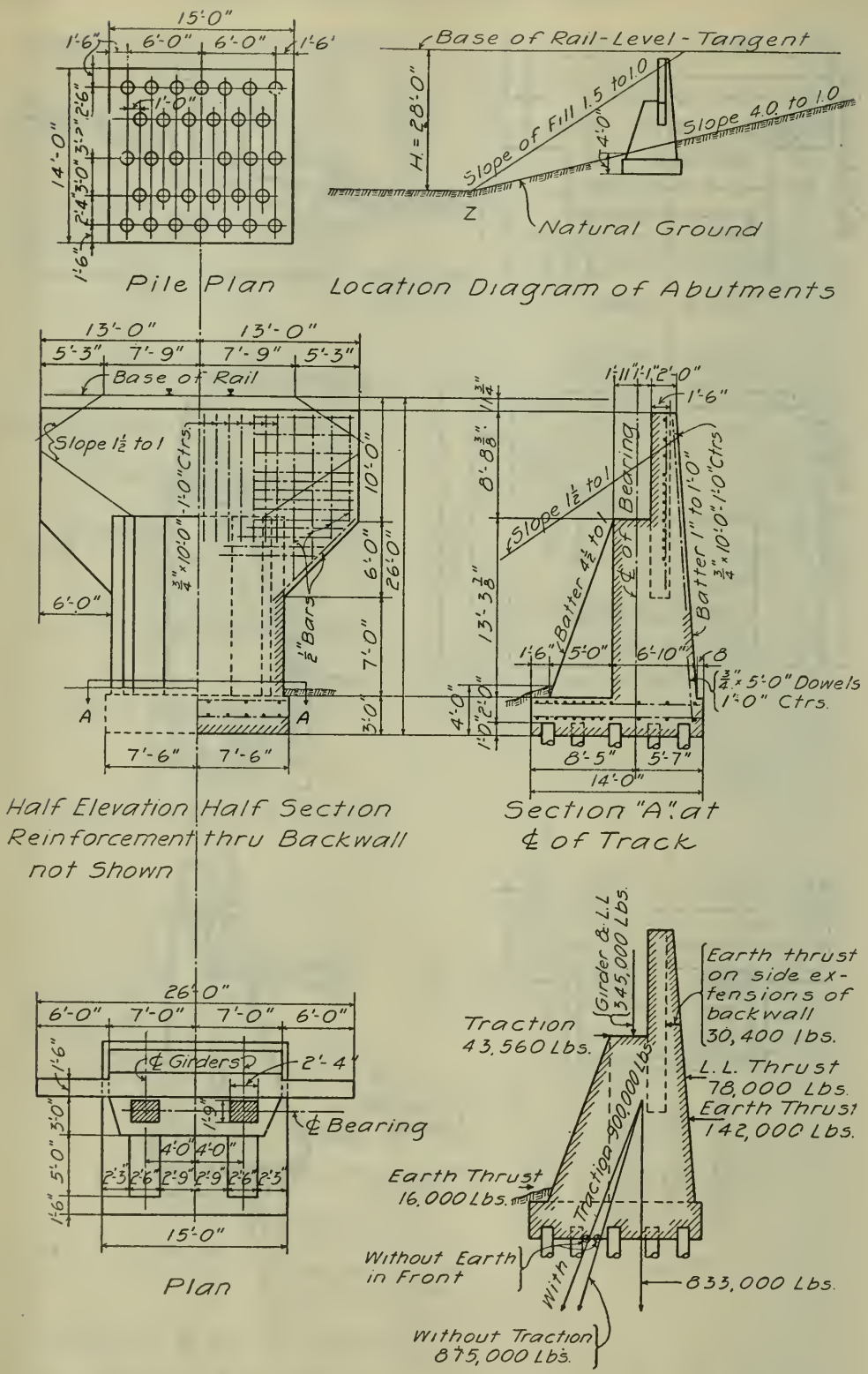
Type B_5 - Plain Concrete Pier Abutment

Fig. 22



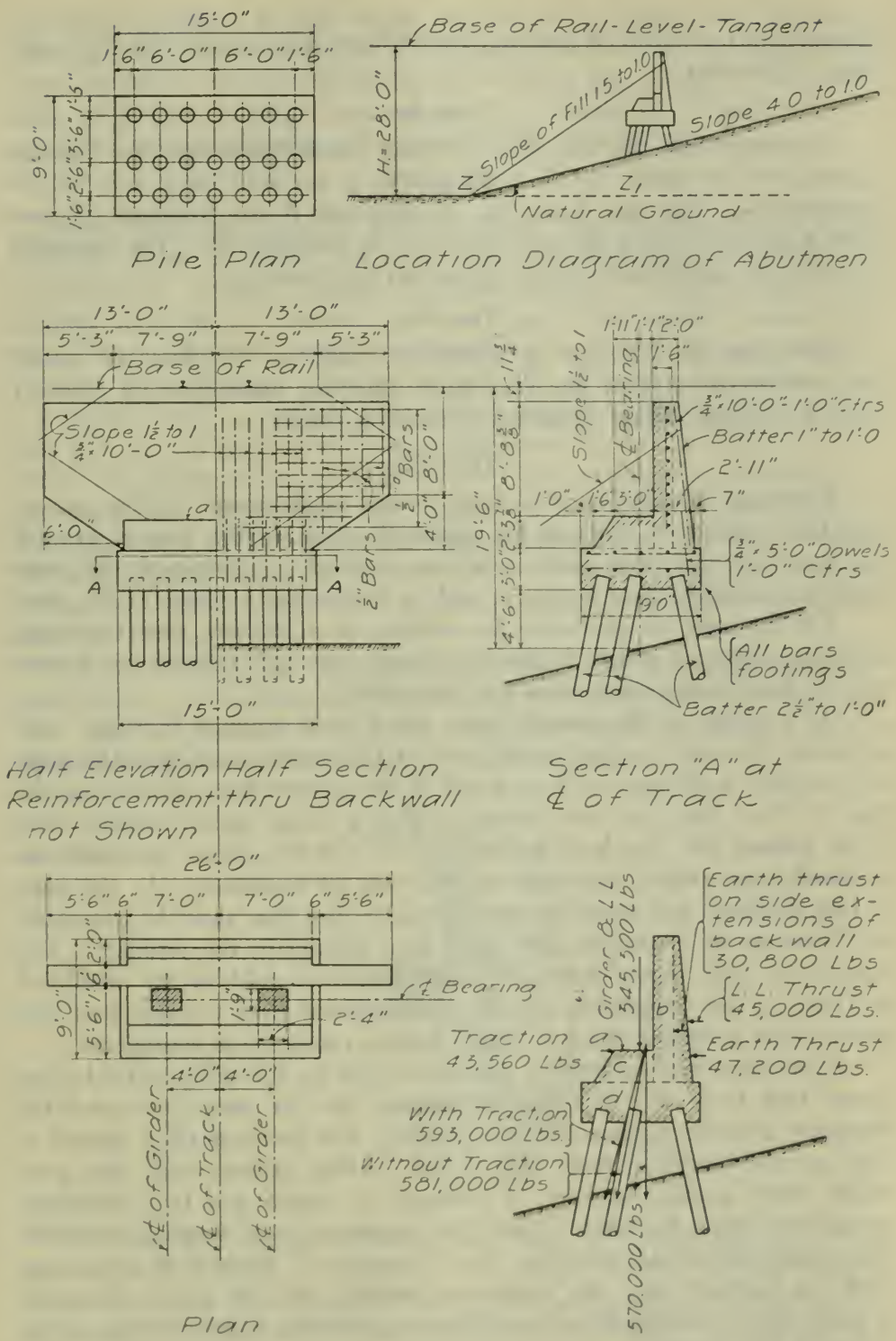
Type B_6 - Plain Concrete Pier Abutment

Fig 23



Type B_7 - Concrete Pier Abutment

Fig. 24



Type B_8 - Concrete Pocket Abutment

Fig. 25

Fig. 43b, this element of cost is an important item, amounting to 59 per cent. of the total.

Type B_6.

Abutment type B_6, Fig. 23, is similar to abutment type B_5, Fig. 22, except that the beam "c_1" in abutment B_5 is replaced by a pier "c_1" in abutment B_6. The side walls "b_2" of abutment B_5 are revolved 90° and form a continuation of the back wall "b_1" in abutment B_6. The abutment possesses no special features not shown on the drawing.

Type B_7.

Abutment B_7, Fig. 24, is similar to abutment B_6, Fig. 23, except that reinforced concrete has been substituted for plain concrete at every point where the change seemed to promise a saving.

Type B_8.

Abutment B_8, Fig. 25, is in turn similar to abutment B_7, Fig. 24, except that instead of carrying the neatwork down to the natural ground, the neatwork has been made only deep enough to distribute the loads from the superstructure and to provide a bearing on the tops of the piles.

The concrete of abutment B_8 consists of a shallow concrete beam, the upper side of which forms the bridge seat "a" (shown in Section B), the lower side resting on a pile foundation.

On account of the natural slope which was assumed in these comparisons, the piles do not extend out of the ground and into the bank for as great a distance as they would if the ground were level along the line "z"-"z_1," Fig. 25, and therefore give a more stable support than if the ground line had been assumed level. On the whole the conditions assumed were rather favorable to this type of abutment. As the piles in this abutment are above the ground water line, they must be creosoted, and concrete or creosoted piles have been figured in the estimate. The piles have been shown battered longitudinally to add to the width of the base of the foundation and its stability, and it is thought that this batter is not a difficult thing to secure from a construction standpoint.

Experience with abutments similar to type B_8, but with vertical piles, shows that there is sometimes a tendency for the bank to crowd the abutment forward against the steel spans. The battered piles, shown in Fig. 25, will partly remedy this defect. After having made this provision there is still, however, a tendency to crowd and two additional precautions must be taken. First, the abutment must receive somewhat more than the usual attention from inspectors. Second, it should be made to support only the expansion bearing for the girder in order to prevent any movement in the abutment producing undue stresses in the adjacent girder span.

It was originally intended that the abutments B_1 to B_8 should only include abutments built throughout of plain concrete, except for a small amount of reinforcement in the back wall, footings, or other places where tension stresses were high. All of the foregoing abutments, except B_7 and B_8, conform to this classification. Abutments B_7 and B_8, however,

resemble abutments B_5 and B_6 in the feature of having the fill extend forward from the abutment at its natural slope without restraint. They were, therefore, included in what were termed the group of plain concrete abutments, although structurally they should be classed with the reinforced concrete abutments, of which a description follows.

Type C_1.

The reinforced concrete wing abutment type C_1, shown in Fig. 26, is similar to the abutment type B_2 of Fig. 15, except that it is constructed of reinforced concrete instead of plain concrete. Commencing at the bottom, abutment C_1 consists: first, of a pile foundation; second, of a deep footing slab "d," which distributes the vertical loads and furnishes a means of anchorage. Resting on slab "d," as shown in Section A-A, is a curtain wall "c_2" which gives lateral support to the earth. The curtain wall is prevented from being tipped outward by the buttresses "c_3," which are anchored to the slab "d." If the abutment is properly proportioned, the curtain wall "c_2" could not be pushed outward by the lateral pressure of the earthwork without carrying with it the buttresses "c_3" and without lifting the slab "d" from the pile foundations and also lifting the entire weight of the earth which rests vertically on the slab "d."

At the front of the abutment, the curtain wall "c_2" is given a horizontal offset "c_1" as shown in Section E-E to provide for the bridge seat "a." The curtain wall is carried up vertically from the bridge seat "a, forming the back wall "b" shown in the same section.

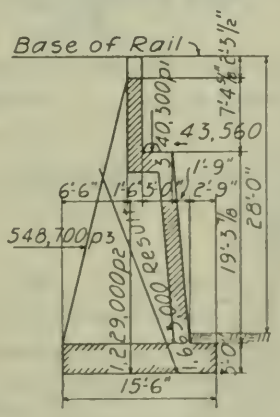
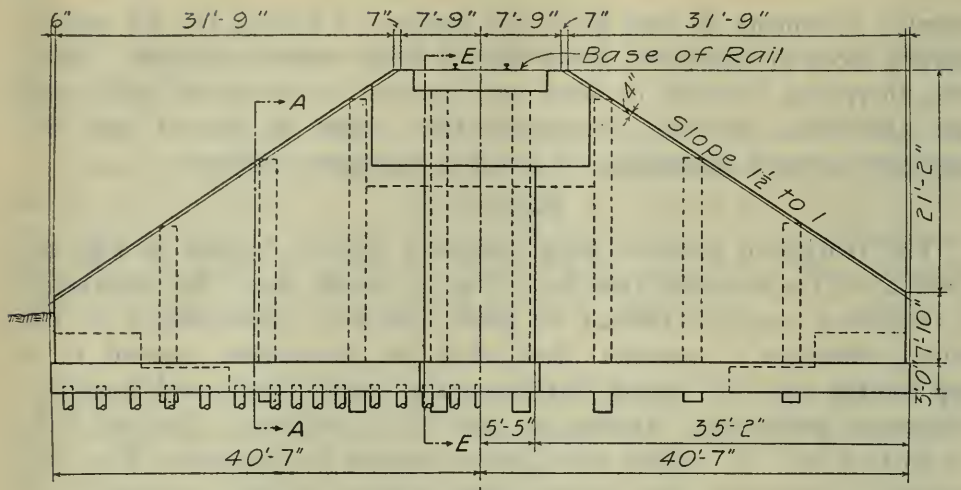
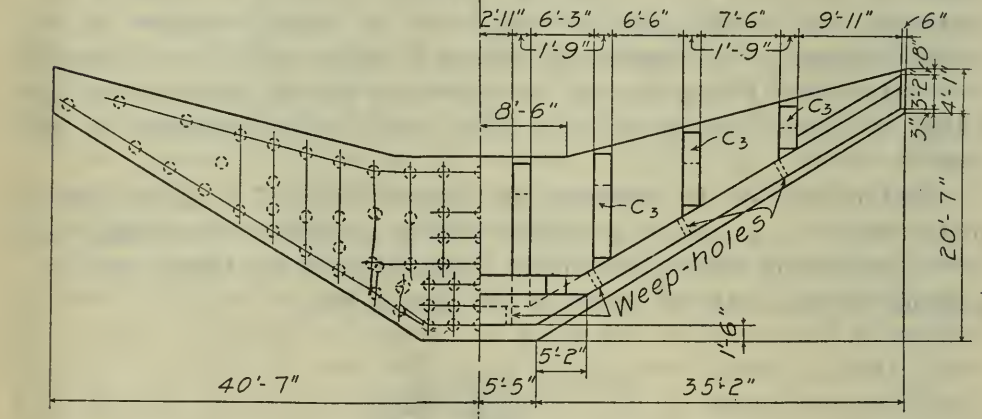


Fig. 26a

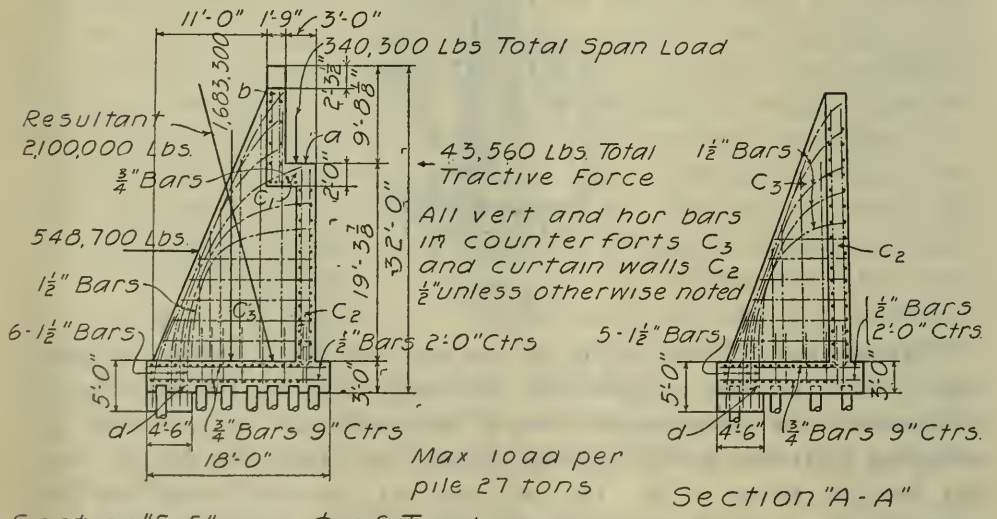
The abutment shown in Fig. 26 has many of the properties of abutment type B_2 but has no particular advantage over it; the introduction of buttresses not decreasing the cost of neatwork and the provisions for anchoring buttresses to the footings greatly increasing the cost of footings for fills above 20 ft. Fig. 26 does not, however, show the best design that can be made of reinforced concrete wing abutment. It contains the two defects of the bridge seat set too far forward and footings with insufficient projection in front of the neatwork, referred to in pp. 11 and 12, in discussion of type B_1.



Elevation



Half Plan of Footings | Half Plan



Section "E-E" near ℄ of Track

Section "A-A"

Type C1 - Reinforced Concrete Counterfort Abutment

Fig. 26

If these defects are corrected we have an improved abutment, such as shown in the cross-section, Fig. 26_a. This abutment, called type C_{1a}, is cheaper than that shown in Fig. 26 and costs considerably less than type B_2 for heights above 28 ft.; estimates showing that it costs about 10 per cent. less than type B_2 for the 36 ft. height and 25 per cent. less for the 50 ft. height which is outside the limits of our diagram.

If, in addition to the economies shown in Fig. 26_a, the sections of all walls and buttresses are reduced to the minimum which can be placed by experienced workers under proper supervision, the economy of type C_{1a} over B_2 is still further increased.

Type C_2.

Abutment type C_2, Fig. 27, is a U abutment of reinforced concrete. It resembles the U abutment of plain concrete in external appearance. Structurally, however, it is quite different.

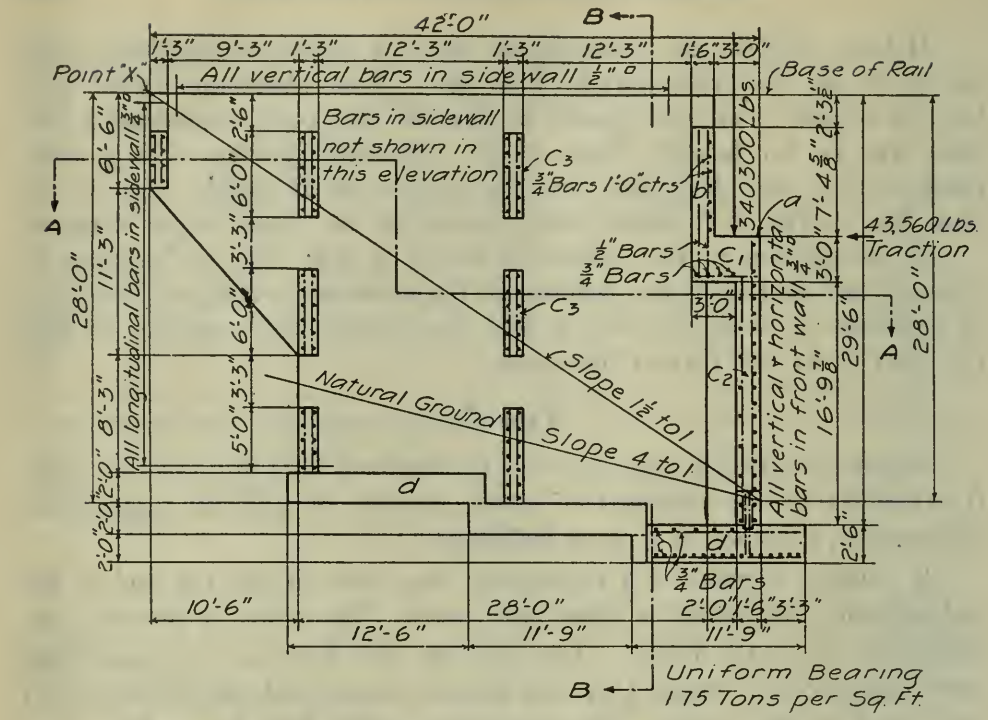
It consists in plan of a rectangular box open at the top and at the embankment end, which is filled with earth. The track is directly supported on the earth filling. The sides of the box "c_4" are prevented from being forced outward by the lateral pressure of the earth by ties "c_3" which connect the two opposite sides "c_4." The front of the box is the curtain wall "c_2," which is a beam between the two side walls "c_4," and restrains the lateral pressure of the earthwork in longitudinal direction.

Commencing at the bottom, then, this abutment consists of foundation "d," which supports the front curtain wall "c_2" and the two side walls "c_4." The front curtain wall "c_2" and the two side walls "c_4" form three sides of a rectangle, the fourth side toward the enbankment remaining open. The front curtain wall "c_2" is carried upward to the point "c_1," where it is offset in horizontal direction, forming the beam "c_1," the upward surface of which is the bridge seat "a." From "c_1" the wall is carried upward forming the back wall "b." The ends of beam "c_1" rest on the side walls "c_4," or on an enlargement thereof "c_5," and the front edge of the beam "c_1" rests upon the front curtain wall "c_2." It is apparent that this type should result in considerable saving in concrete over the same type constructed in plain concrete, which is called "B_3."

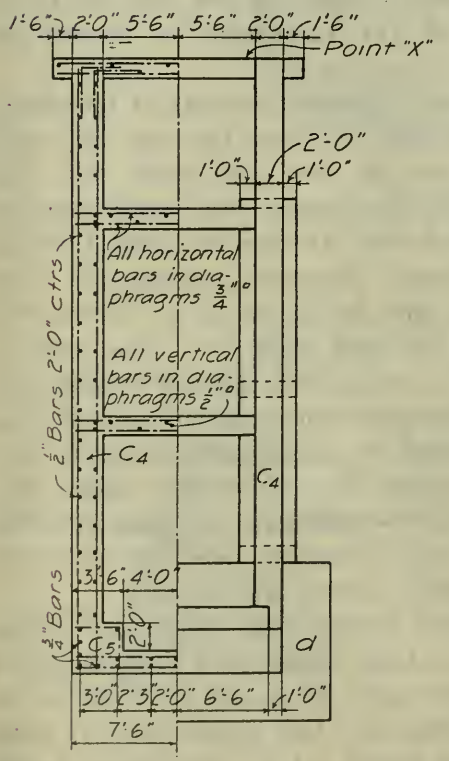
If the design C_2, Fig. 27, were to be constructed of plain concrete, the side walls "c_4" would have to be made about as shown by the dotted lines "e--e" in order to make them stable against overturning.

Considering only the upper portion of the side walls "c_4," where the economy of introducing the tie is least apparent, a comparison of restraining the side wall against overturning by means of a tie or by means of its own weight is shown in Fig. 28. One square inch of metal is imbedded in the rectangular concrete tie "h i f g," and carries a load of 13,500 pounds at the assumed unit stresses, and if this tie is 5 ft. above the corner "k" on which the side wall tends to rotate, the effective moment against overturning furnished by the tie is 67,500 ft. lbs.

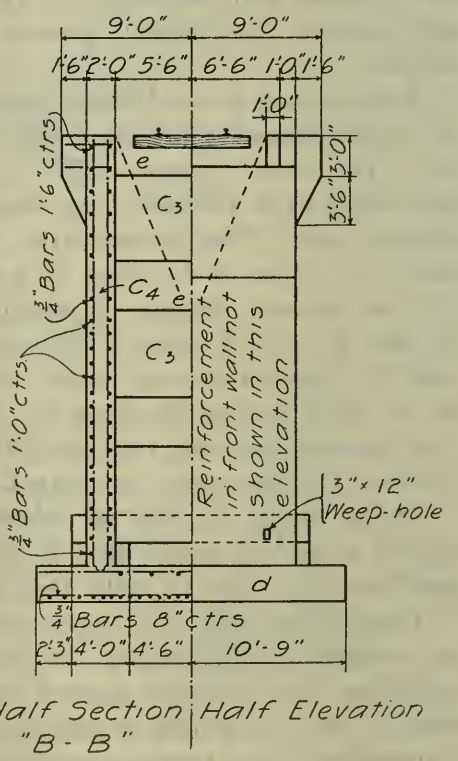
Let "p_1" represent the weight of the concrete in the triangle "b a c."



Section at ℄ of Track



Half Section Half Plan
"A-A"



Half Section Half Elevation
"B-B"

Type C2 - Reinforced Concrete "U" Abutment
Filled - Long Side Walls

Fig. 27

Let "m" be the center of gravity of the triangle "b a c." Assume the lever arm of the force "p_1" to be equal to the lever arm of the force "p_2," which represents the stress in the tie bar. If the sketch is representative, it will take 3.38 yds. of concrete at 4,000 lbs. per cu. yd. to produce the same resisting moment by means of the force of gravity as is produced by the tie rod "p_2," which ties the two walls together.

Comparing the quantities in the foregoing paragraphs, we have:

(1) Gravity retaining wall:

3.38 yds. of concrete for one side wall.
6.76 yds. of concrete for two side walls.
6.76 yds. at $5.00 per cu. yd. (material, mixing and placing same) $33.80

(2) For the thin wall with steel tie:

15 linear ft. of one inch square steel bar, at 3.4 lbs. per linear ft = 51.1 lbs.
51.1 lbs. at 3½ cents per lb..... $ 1.78
15 cu. ft. of concrete = .56 yards.
.56 cu. yds. at $10.00 per cu. yd..... 5.60

$ 7.38

The above approximate comparison of a small part of the C_2 abutment with the corresponding part of B_2 abutment gives a ratio between the parts compared, of 21 per cent.

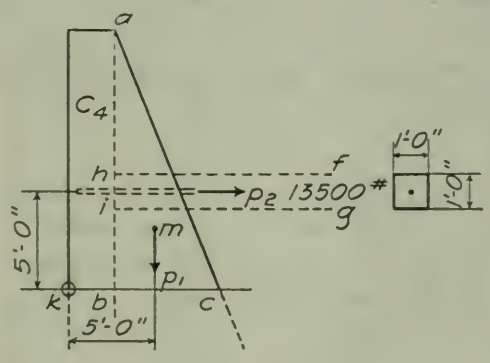


Fig. 28

As shown in Fig. 44 the actual cost of the type C_2 abutment is about 75 per cent. of the B_2 abutment. The foregoing comparison is, therefore, only a rough analogy. It illustrates, however, in a general way the source of economy of abutment type C_2.

This abutment type C_2 easily satisfies the requirements of "m_1" and "m_3" against overturning, of page 9. The width of footings, measured along the center line of track, which is effective against overturning of type B_2, is 13 ft. 9 in. That of type C_1 is 18 ft. The corresponding dimension on abutment C_2 is the distance from the front to back of abutment, or 45 ft.

It is true that the wing walls of abutments B_2 and C_1 protect, perhaps, five times as much of the embankment against scour as does abutment C_2,

but if we compare the protection afforded by either type B_2 or C_2 with the total amount of bank protection required, the difference between the two abutments in this respect is not much. One of the defects of this abutment is that practically all of the surface water from the track for the entire length of abutment must drain past the point "x," Figs. 27 and 29. As the amount of water is considerable it tends to wash away the embankment at the end of the wing wall, as shown in Fig. 29. The washing of the bank at this point is, of course, an important matter, as the material is washed away at a point not far from the end of the track ties and requires much more attention than if the material was washed away at the end of the wing wall, as shown in Fig. 20.

In Fig. 30 is shown an abutment of an entirely different structure, but which is exactly the same as abutment C_2, as far as drainage is concerned. Fig. 30 shows the loose rock and boards necessary to maintain the shoulder of the bank on account of drainage. Drainage openings are provided in the front and side walls of abutments C_2; but even with this provision it is not as easy to drain as type B_2 or C_1, unless it is filled with porous material.

Type C_3.

In Fig. 31 abutment type C_2 is shown in dotted lines and is shown to be 42 ft. in length. If the approach span is lengthened, the face of the abutment can be moved from "a" to "b," thus shortening the abutment by 16 ft. This shortened abutment, which is shown in full lines, is called type C_3, and is similar in every way to type C_2 except that it requires a longer approach span and that it permits the fill to spill around the front of the abutment.

Type C_4.

Abutment type C_4, Fig. 32, and all of the abutments which follow have one feature differing from any of the abutments previously mentioned. Abutments C_4, C_5, C_6 and C_7 have the common feature of carrying the track directly on the body of the abutment over the entire length of the abutment instead of on the bank. Commencing at the top, abutment type C_4, Fig. 32, consists of a slab "a_2" resting on the side walls "c_4," the side walls in turn resting on the footings "d." The side walls "c_4" are tied together in front by the curtain wall "c_2;" this curtain wall being offset to form the bridge seat "a" and the back wall "b" in a manner similar to that used in abutment type C_2. The curtain wall "c_2" of abutment C_4 is not required to carry any of the lateral pressure of the earthwork, however, as in this abutment the earth is allowed to spill into the interior of the abutment and around on the outside, assuming its natural slope from "x" to "z," here assumed at 1½ to 1. The side walls "c_4" are tied together by the ties "c_3."

To save material and to equalize the pressure of the earthwork on both sides of the side walls "c_4," two large openings "c_6" are made in the walls. The portion of the side wall remaining between the openings "c_6" forms a column; and the portion of the side walls above the openings forms a beam between columns. A portion of the completed

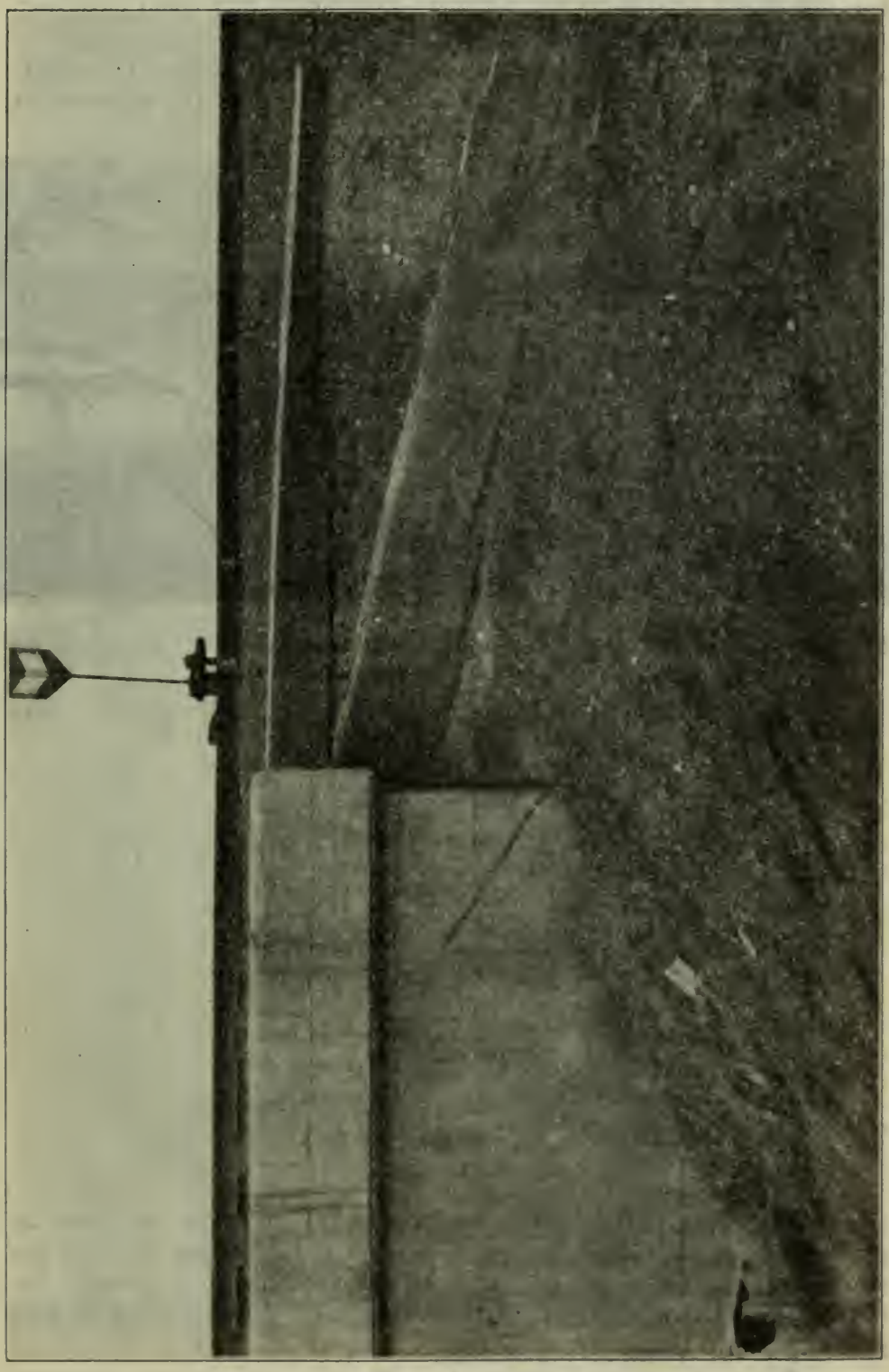


FIG. 29—EMBANKMENT WASHED AWAY AT END OF WINGWALL OF U ABUTMENT.

abutment type C_4 having one panel only, is shown in Fig. 33. The openings are shown circular on top, although structurally they could have been as easily made square.

Abutment C_4 has an advantage over abutment C_2 in that its foundation loads are less, due to the fact that the interior of the abutment is

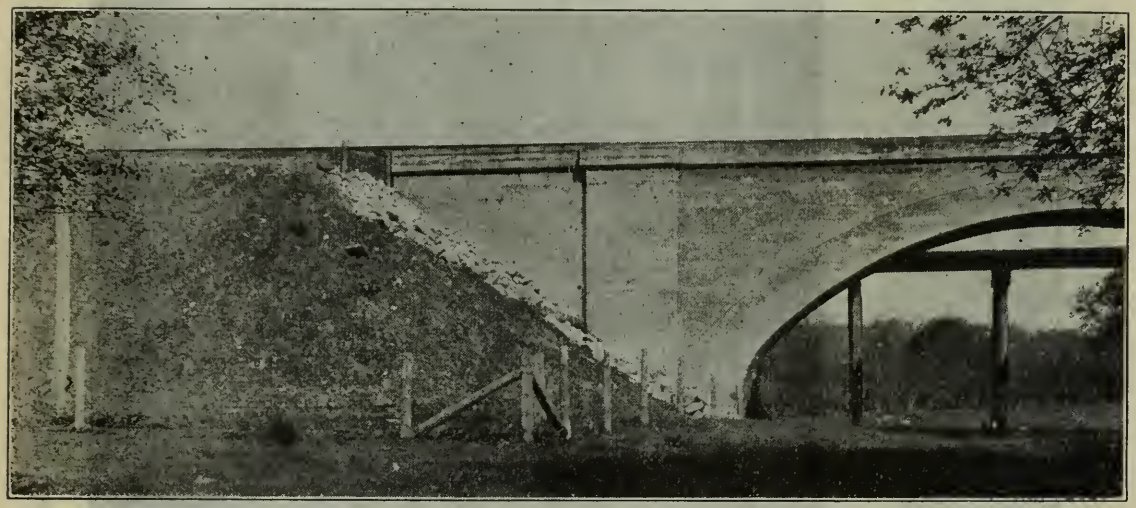
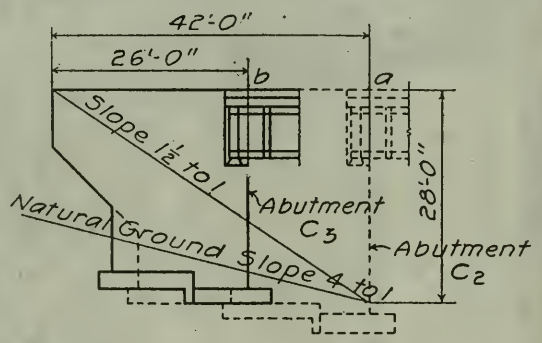


FIG. 30—LOOSE ROCK AND BOARDS REQUIRED TO MAINTAIN THE SHOULDER OF THE BANK AGAINST DRAINAGE WATER.

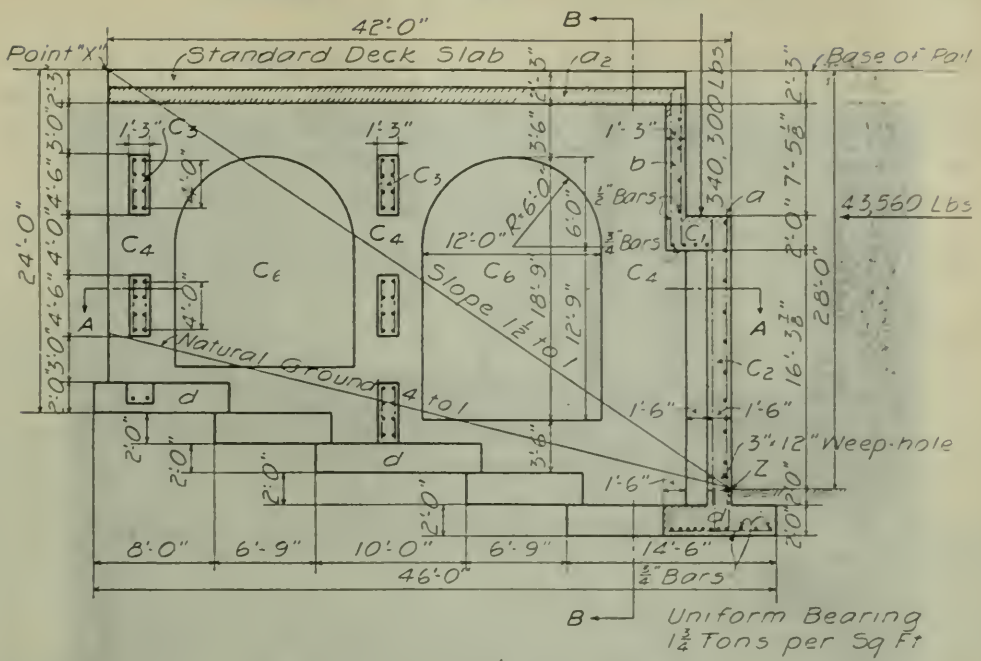


Abutment Type C_3 shown in full lines.
Abutment Type C_2 shown in dotted lines.
Type C_3 Reinforced Concrete "U" Abutment-Filled-Short Sidewalls

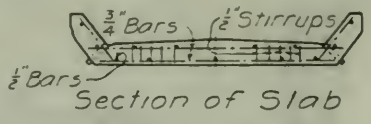
Fig. 31

only partially filled with earth. The side walls of C_4 are subjected to practically no unbalanced lateral pressure of the earthwork. It has the disadvantage that it requires a considerable amount of material for the construction of the floor slab "a_2," and as a consequence it does not show much economy for low fills.

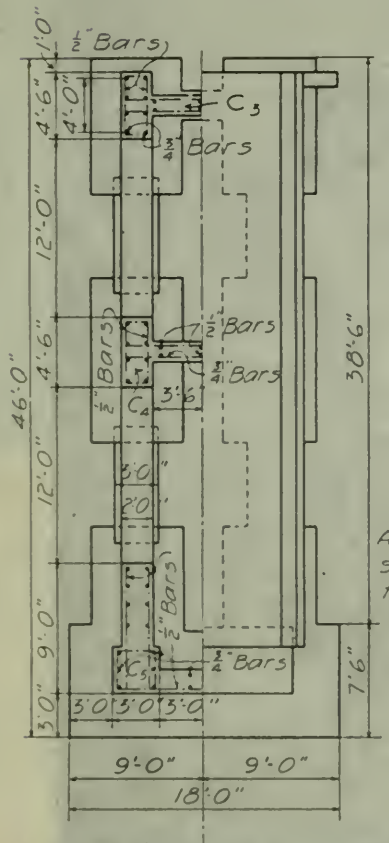
In Fig. 34 a completed abutment of this type with the fill in place is shown. The embankment in Fig. 34 has an average slope along the face of the side wall of about 1 to 1 instead of the slope 1½ to 1 which



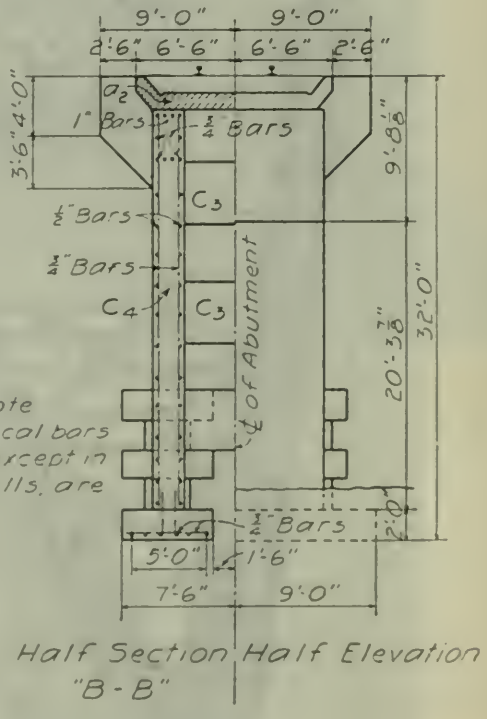
Section at ℄ of Track



Section of Slab



Half Section Half Plan
"A-A"



Half Section Half Elevation
"B-B"

Note
All vertical bars shown, except in the walls, are ¾" ø

Type C_4 - Reinforced Concrete "U" Abutment - Covered

Fig. 32

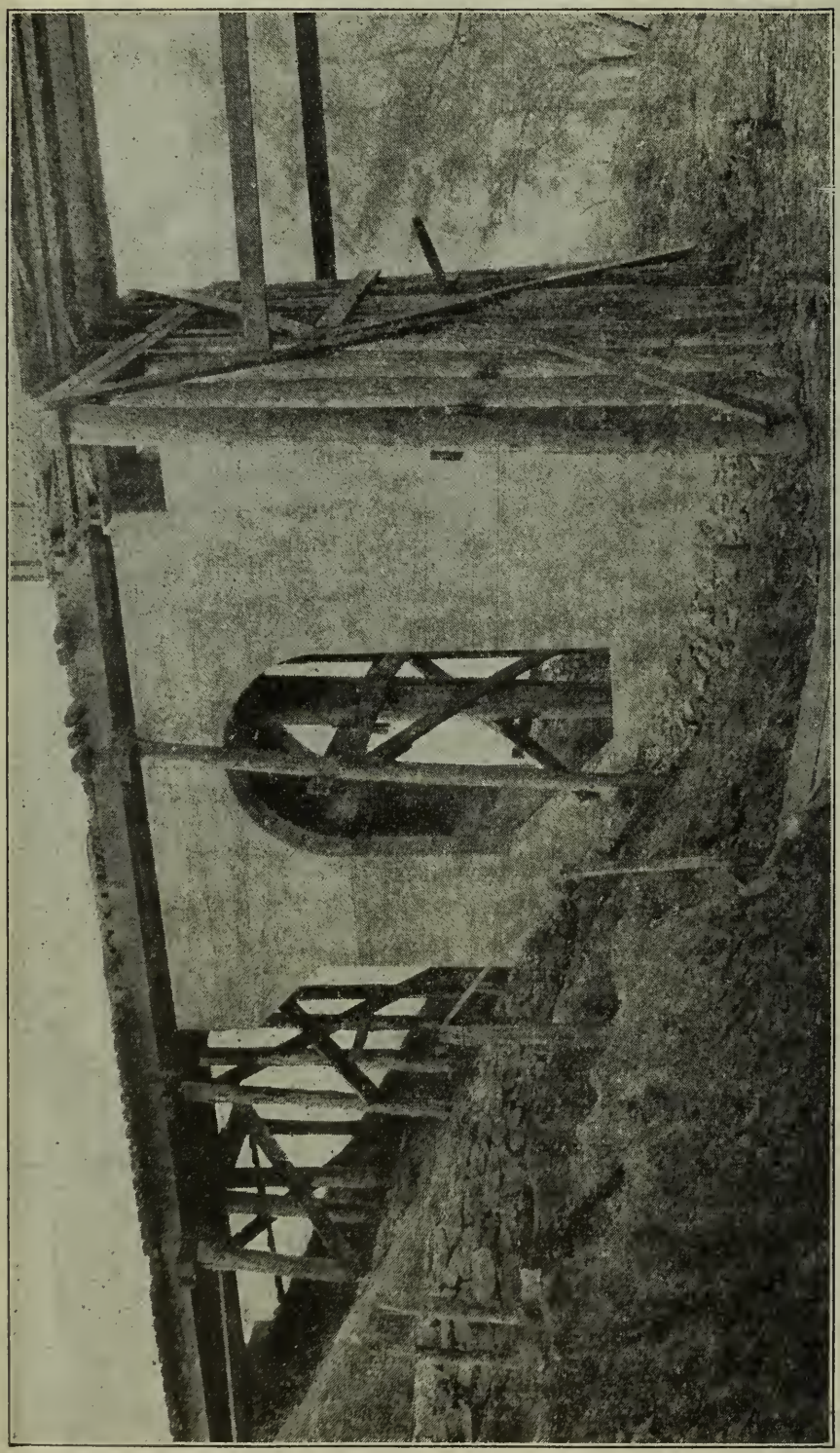


FIG. 33—ABUTMENT, TYPE C_4.

was used in the design in Fig. 32. The quantities for abutment type C_4 were all figured on a 1½ to 1 slope, so that at a later point when we compare the costs of various types it is not necessary to make allowance for rip-rap used with type C_4, Fig. 34. Fig. 35 is a general view of the bridge in which a type C_4 abutment was used at each end. The abutment on the left-hand side is the same abutment which is shown in Fig. 34.

As there are practically no unbalanced lateral earthwork pressures in action against abutment C_4, no provision need be made to make it conform to the requirements "m_1," "m_2" and "m_3" on page 9. This abutment gives, perhaps, slightly less protection to the embankment against

FIG. 34—COMPLETED ABUTMENT, TYPE C_4, FILL IN PLACE.

scour than abutment C_2, but it will probably not wash away at the shoulder of the embankment at "x," as drainage for the top of the abutment is provided through holes in the sides of the floor slabs. It is, of course, easily drained, and if a ballasted deck is used on the girder, as shown in Fig. 35, it provides a continuous support of the same character for the track on the abutment and on the superstructure, as shown in Fig. 36. The ties in the foreground, Fig. 36, are the ties of the pile trestle which have not yet been removed, the trestle having just been replaced by an earth embankment.

Type C_5.

Abutment type C_5, Fig. 37 and Fig. 38, consists in general of six vertical posts "c_4" and "c_6," which support the slab "a_2." At the bottom they

are tied together by the footings "d_1" and "d_2." The footings "d_1" and "d_2" act partly as foundation beams and partly as ties, which hold the bottoms of columns in their true relative position and afford them support against any unbalanced lateral pressure of the earthwork.

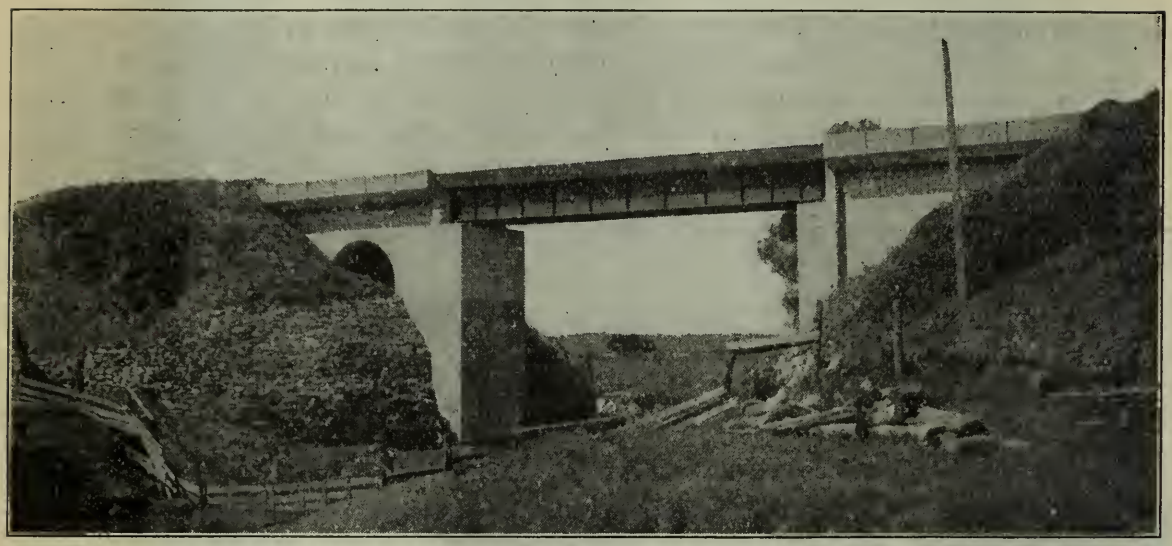


FIG. 35—SPAN SUPPORTED ON TYPE C_4 ABUTMENTS.

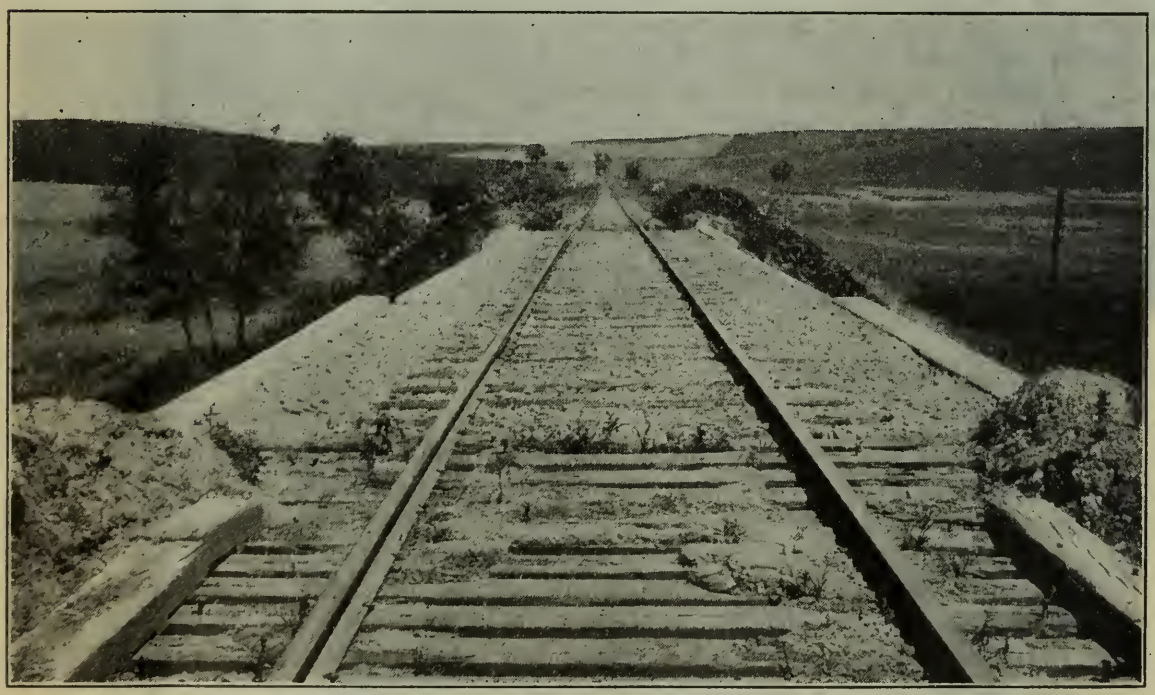
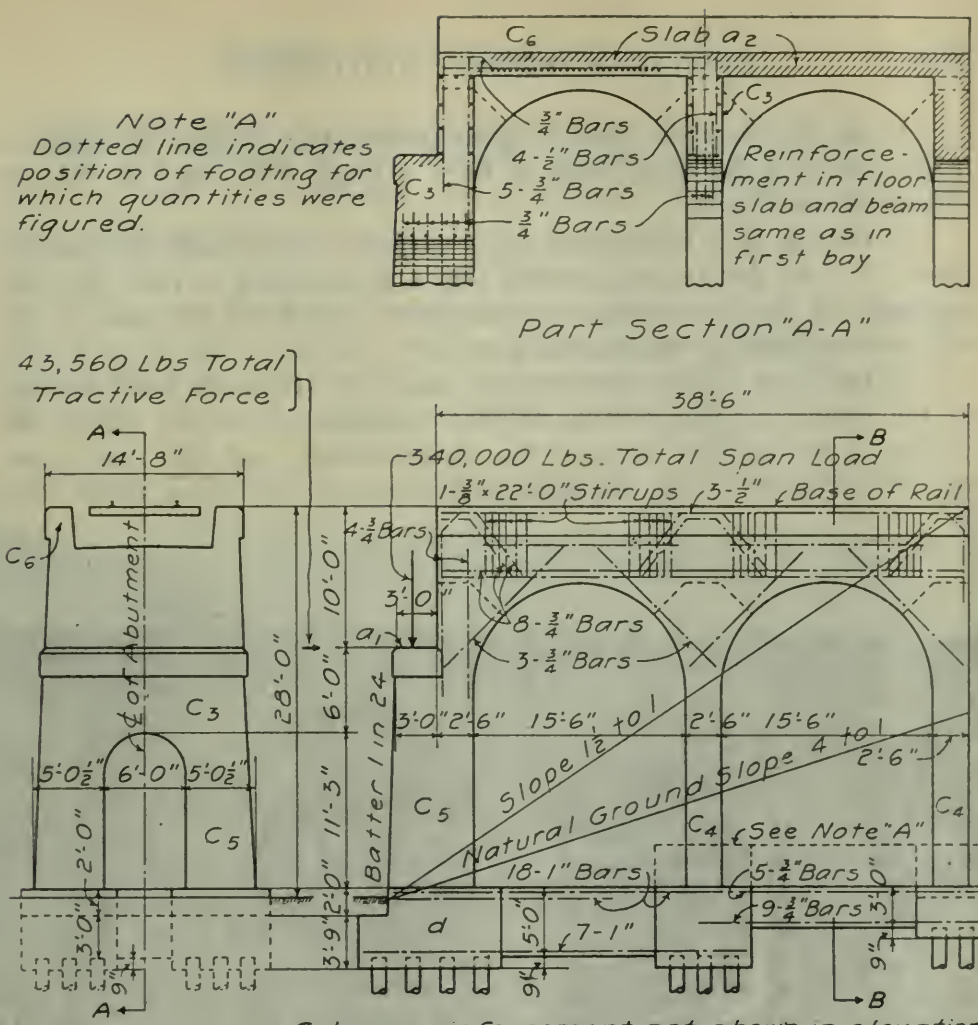


FIG. 36—TRACK SUPPORTED ON SLABS OF TYPE C_4 ABUTMENT.
Ties in the Foreground are the Ties of the Pile Trestle Which Have Not Been Removed, the Trestle Having Just Been Replaced by an Embankment.



Type C_5 - Reinforced Concrete Arch Abutment

Fig. 37

At the top the cross beam c_8 spans transversely between the posts c_4. Two posts and the cross beam c_3 form a single bent, such as the one called "A" in Fig. 23.

At the top, also, longitudinal beam c_6 spans longitudinally between the bents "A." By this arrangement the slab a_2 is supported on four sides, the two ends of the slab resting on cross beams c_3, and the two sides of the slab are supported by longitudinal beam c_6.

At the front of the abutment the posts "c_5" are made much heavier, as the beam "c_3" which connects them together at the top carries the weight of the adjacent span of the superstructure, and also carries one end of a slab "a_2." The divisions mentioned are only those which have

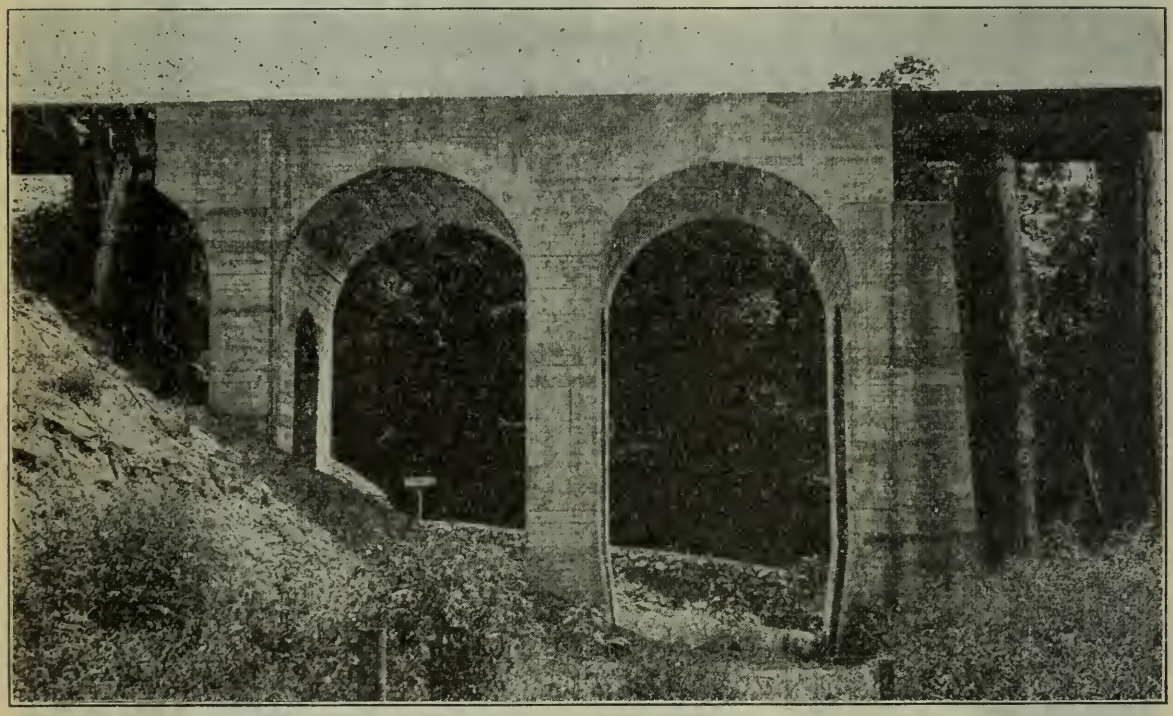


FIG. 38—COMPLETED TYPE C_5 ABUTMENT.

to be made in order to execute the design; the structure itself being tied together by steel in all directions so as to resemble a monolith. In service this abutment has all the advantages and disadvantages of type C_4, which it resembles structurally in many respects. As it is somewhat more open than type C_4, it drains itself a little better. A completed abutment of this type is shown in Fig. 38. The opposite side of the same abutment after filling is shown in Fig. 39, and a general view of a bridge having an abutment of this kind at each end is shown in Fig. 40. The abutment at the right end of Fig. 40 is the same abutment of which a nearer view is shown in Fig. 39. The rip-rap shown in Fig. 39 was due to the special requirement of the situation where this abutment is built and would not ordinarily be required.

Abutment shown in Fig. 37 is the design of W. S. Lacher.*

The first abutment of this character of which the writer had knowledge was built by the Illinois Central Railroad and photographed, but never published.

Type C_6.

A T abutment of reinforced concrete type C_6 is shown in Fig. 41. The stem of this abutment consists of a slab "a_2," which is supported longitudinally along its center line by the central wall of the stem "c_4." The wall is carried vertically down to the spread footings "d."

Fig. 39—Completed Abutment, Type C_5, Fill in Place.

The floor "a_2" with the wall "c_4" are given lateral stability against overturning by the front curtain wall "c_2" and by the reinforcement on both faces of the wall "c_4," which extends directly into the footings. The curtain wall "c_2" is carried up to form the bridge seat "c_1" and the back wall "b" is in the same manner as in the C_4 abutments.

This abutment has the defect that it is not safe under a derailed locomotive. The derailed locomotive produces in this structure much greater stresses than in the other types.

If we increase the reinforcement to take care of the exceptional case of a derailment, we need a quantity of steel nearly double that shown in

*A similar abutment, called Fig. 6, is described in the article by Wm. M. Torrence in the "Engineering News," January 11, 1906. Also in the "Engineering News," August 18, 1910, pp. 180—"Abutments for the New York State Barge Canal."

the table, increasing the cost of reinforcing steel practically $400 and filling the structure so full of bars that the cost of laying the concrete would be largely increased.

Provision for derailment in this structure is, therefore, out of the question, and its weakness under a derailment must stand a grave defect.

We can offer little additional information concerning type C_6 and the following type C_7, other than that shown on the drawings. The advantages and defects of the several features of these abutments are the same as the advantages and defects of the same features in the foregoing abutments, which were described more fully.

Type C_7.

The trestle abutment type C_7, Fig. 42, in a general way is a concrete trestle of sufficient length to carry the track from the point "z," or from the end of the superstructure, to the point "x," where the bank

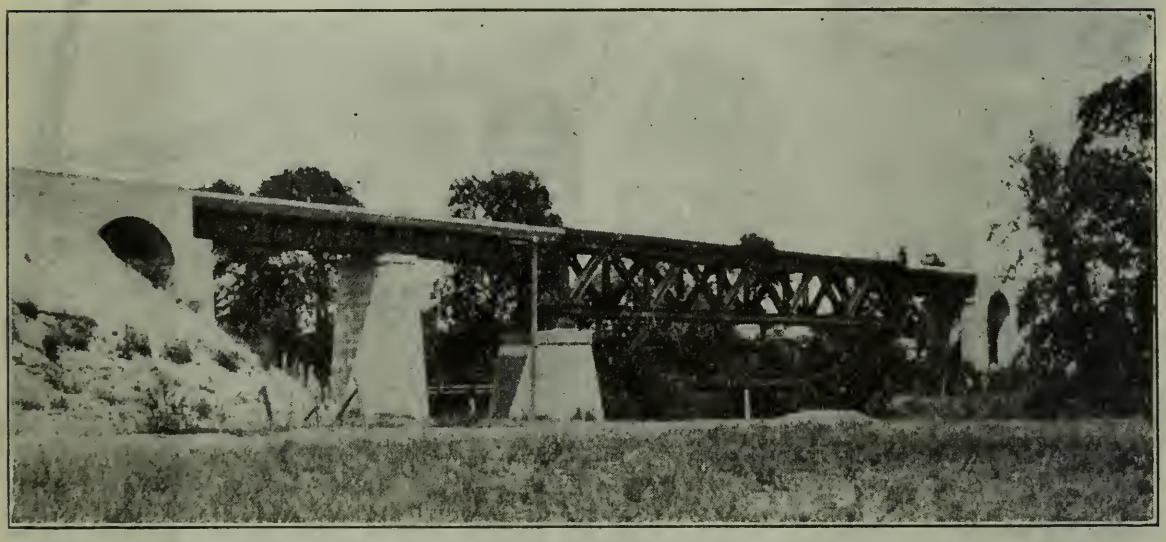
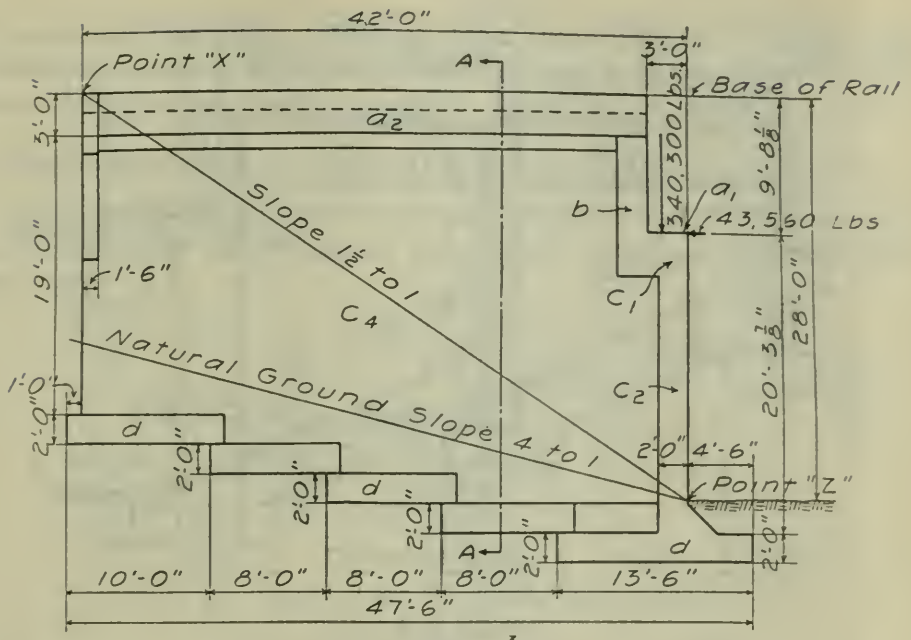


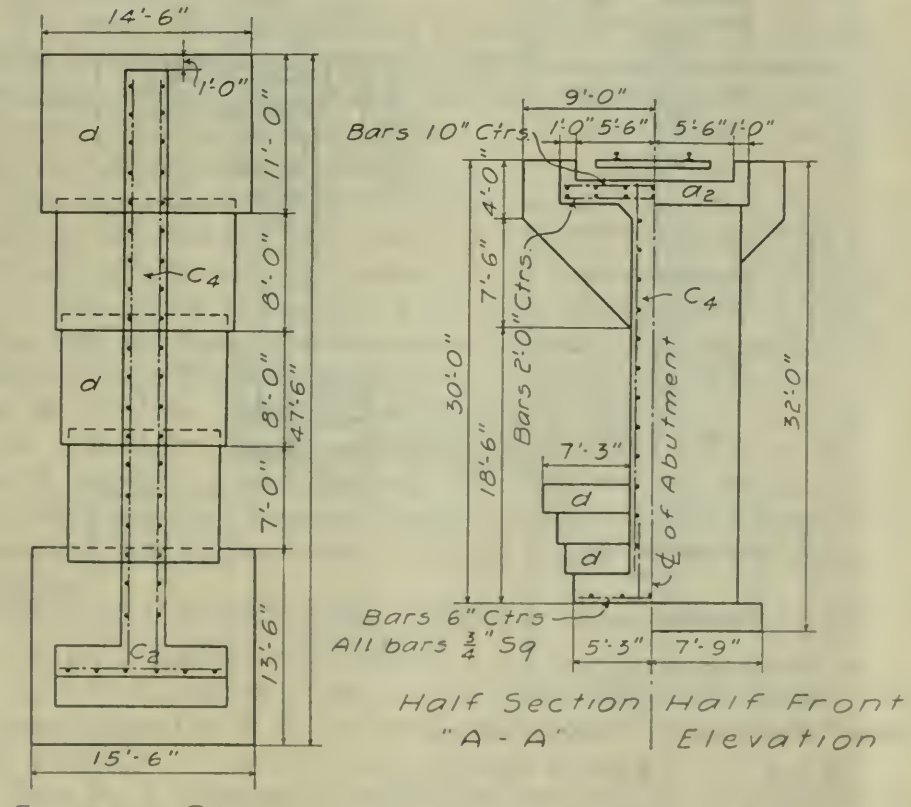
FIG. 40—BRIDGE TERMINATED AT EACH END WITH TYPE C_5 ABUTMENTS.

has attained its full height. Commencing at the top, this abutment consists of two standard U-shaped trestle slabs "a_2" which contain the ballast, which in turn supports the ties and rails. These slabs rest on the neatwork of the bents "c_2" and "c_4," which are ordinarily reinforced concrete trestle bents with spread footings "d." To resist unbalanced longitudinal pressure of the earthwork and also to add longitudinal stability to the abutment, the struts "c_3" are introduced between the tops of the bents "c_2" and "c_4," and the struts "d_1" introduced between the bottoms of the same bents. In addition to acting as struts these members "c_3" and "d_1" combine the three bents and the two spans into two rigid quadrilaterals. The trestle bent "c_2" at the front end of the abutment is made considerably thicker than the bents "c_4" in the bank in order to leave room for the bridge seat "a_1." In service this abutment is much like C_4 and C_5. Structurally it resembles C_4 more closely in that the floor "a_2" is a separate member and can be placed after the



Uniform Bearing $1\frac{3}{4}$ Tons per Sq Ft.

Elevation



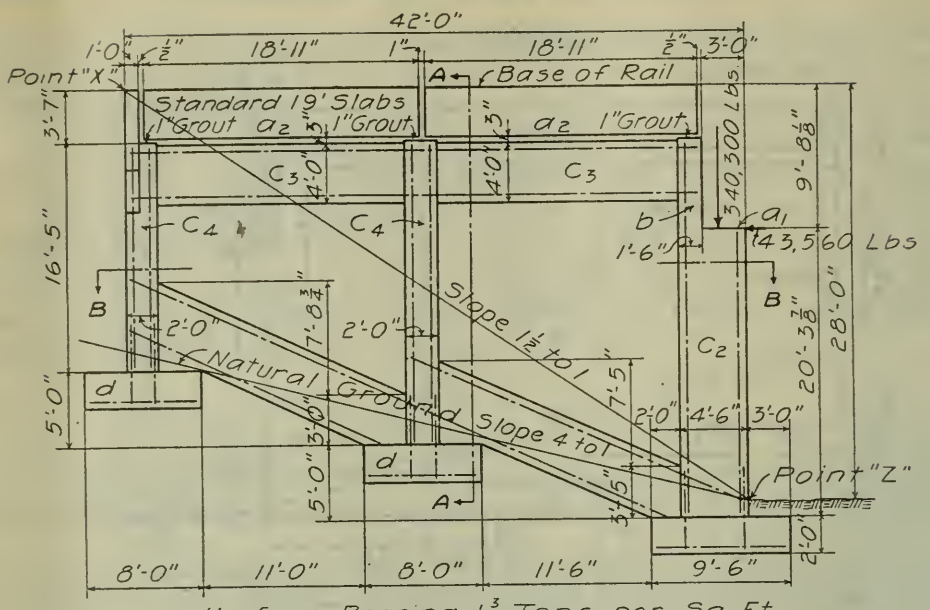
Footing Plan

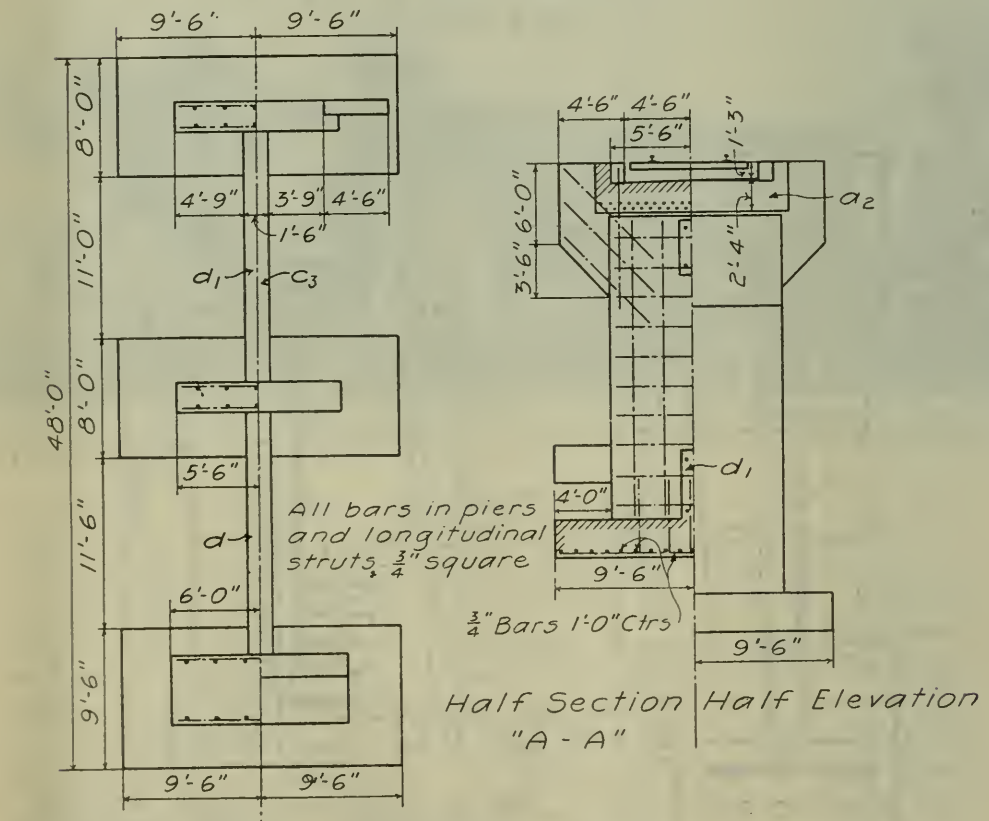
Half Section "A - A"

Half Front Elevation

Type C_6 - Reinforced Concrete "T" Abutment

Fig 41





Type C_7 - Reinforced Concrete Trestle Abutment

Fig. 42

abutment has been built. The remaining portion of the abutment forms a complete structure without the slab. The slab is only used to afford direct vertical support to the track.

MEMORANDUM ON TOTAL COSTS OF VARIOUS TYPES.

Figs. 43a to 43g, on inserts, pp. 44-45, are tables which show the manner in which the total estimated costs of the foregoing abutments were made up.

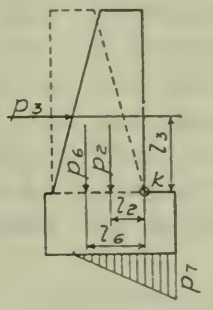


Fig. 43

These tables should give dependable estimated costs, as the division of the total costs into their elements has been carried as far as could be conveniently done.

The tables show the quantities as well as the unit costs and make it possible for the reader to substitute different unit costs for those shown, where the conditions are such that the unit costs given in the table would not apply. It is not believed, however, that any ordinary changes will affect the relations between the totals.

Figs. 44 to 64 contain curves which compare the cost of the several abutments for different heights and for different types. On Fig. 44 the total cost of abutments are platted as ordinates to the heights platted as abscissas. Each of the Figs. 46 to 58, inclusive, shows the total cost of one type and shows also the manner in which the cost of that type is divided between neatwork, foundation, embankment, etc. In each figure from 59 to 64 are platted curves showing a single element of cost in all the abutments, Fig. 59 containing curves which compare the total cost of neatwork of any type with the total cost of neatwork in any other type, and Figs. 60 to 64, inclusive, contain similar curves for the foundation, floor, embankment, additional length of superstructure and falsework.

The total cost of the various types of concrete abutments are platted, Fig. 44, the following being omitted:

Type B_1 is omitted, except for the 28 ft. height, the design having so many defects that it did not seem worth while to estimate its cost for other heights.

Type B_4, T abutment, is omitted because most of its properties can be obtained from an examination of the figures and curves illustrating Type B_3.

Curves showing the cost of all the other types are platted.

The objection most frequently made to abutments types C_2 to C_7 is their high cost, especially, it is said, if constructed by men experienced mostly in the construction of plain concrete work.

On account of this objection the principal unit costs for this type were taken rather high, as it was believed that there was enough economy in the design of some of these types to more than offset the highest unit cost which could be reasonably selected. Examination of Fig. 44 will show that this prediction was substantially correct.

In order to furnish information as to the cost of these abutments if lower unit prices were selected, the curves shown in Fig. 44 have been reproduced in Fig. 45. The total costs have been reduced, however, so that Fig. 45 shows average low costs under ordinary circumstances, which are about 37.5 per cent. less than those shown in Fig. 44.

In examining these cost curves the following should be noted:

Types C_6 and C_7 are untried, and unexpected weaknesses may develop in their use.

C_6 does not take care of derailment.

B_5, B_6, B_7, B_8 or C_7 cannot be used where much scour is anticipated or where the highwater is near the bridge seat, without the use of rip-rap, whose cost has not been included.

It should be observed that the necessity of carrying the footings further below the ground will make a proportionately greater increased cost in types B_1 to B_7 than in types C_2 to C_7.

The use of any type of superstructure which gives a less depth of bridge seat below base of rail will mean a greater proportionate increase in cost in types B_1 to B_7 and C_6 than in types C_1 to C_5 and C_7.

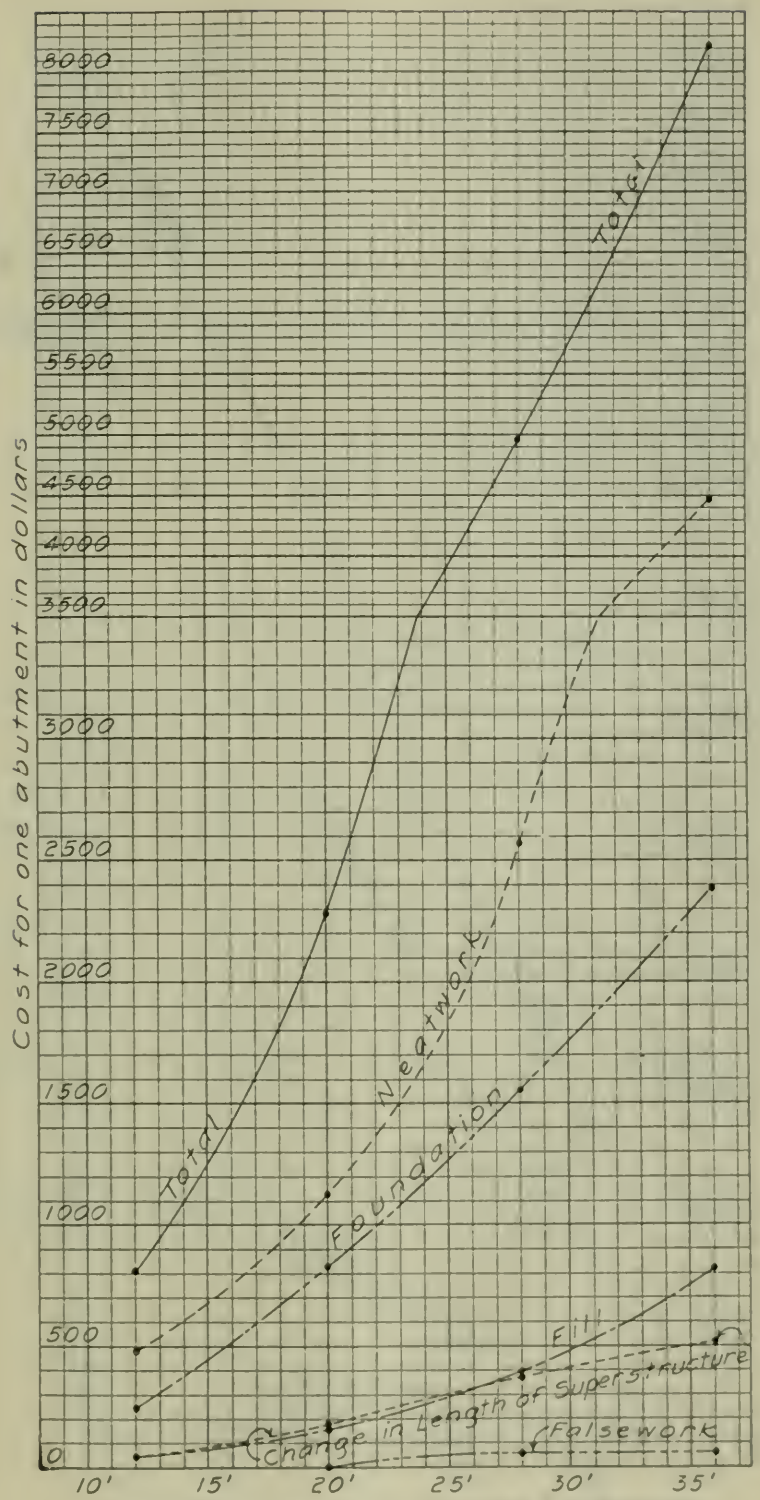
With these points in mind the cost curves permit the reader to draw his own conclusions as to the relative economy of the various types in different situations.

Type C_1 is highest in cost of any abutment for heights over 21 ft. As previously mentioned, this type is created by the substitution of reinforced concrete in a mediocre design intended for plain concrete, making the least number of changes in the design which would permit the use of the new material.

If this design is improved, as shown in Fig. 26_a, its cost can be reduced by an amount which will make it of less cost than type B_2, for heights above 28 ft. If, as mentioned on page 27, advantage is taken of other known refinements in design of abutments of this character, its cost can be still further reduced.

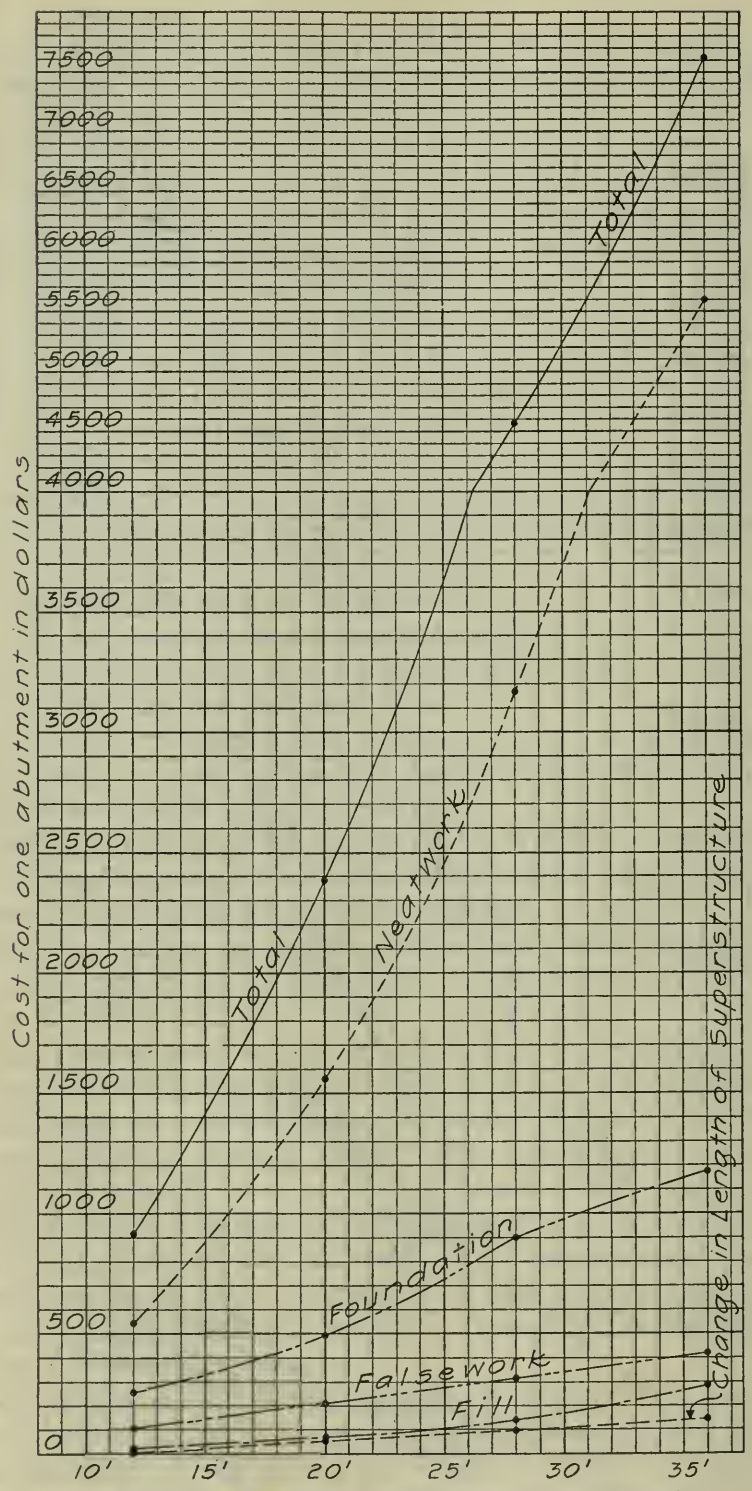
The equality of cost shown for types B_5, B_6 and B_7 is not accidental but is due to the similarity of these types, and is explained by an examination of Figs. 59, 60, 62, 63 and 64, which show that not only the total cost of these abutments is alike, but that the cost is proportioned in a similar manner, in all abutments between neatwork, foundation, fill, additional length of superstructure and falsework.

For nearly all heights types C_3, C_6 and C_7 are the lowest in cost of those types in which the neatwork is carried to a sufficient depth to place footings on the natural ground.



Type B_2

Fig. 46



Type B_3

Fig. 47

Estimate of Quantities and Costs

	Height in Ft.	Item	Neatwork			Footings			Cu. Yds. of Excavation	Piles	Cu.Yds. of Fill	Falsework	Change in Length of Bridge One Abutment	First Total	Engng.& Incidentals	Grand Total
			Cu. Yds. of Conc.	Lbs. of Steel	Sq. Yds. of Forms	Cu. Yds. of Conc.	Lbs. of Steel	Sq. Yds. of Forms								
B_2	12	Quantities	60	270	121	21		23	65		170		.71 ft.			
		Unit	$5.00	3½¢	$1.20	$5.00		$1.20	$1.50		$0.25		$61.00		5%	
		Cost	$300	$9	$145	$105	0	$28	$98	0	$43	0	$43	$771	$38	$809
	20	Quantities	160	270	220	56		49	120	34	600		2.79 ft.			
		Unit	$5.00	3½¢	$1.20	$5.00	0	$1.20	$1.50	$8.00	$0.25		$61.00		5%	
		Cost	$800	$9	$264	$280		$59	$180	$272	$150	0	$170	$2194	$109	$2293
B_1	28	Quantities	406		425	103		63	260	71	1500		4.42 ft.			
		Unit	$5.00		$1.20	$5.00		$1.20	$1.50	$8.00	$0.25		$61.00		5%	
		Cost	$2030	0	$510	$515	0	$76	$390	$568	$375	$50	$270	$4783	$239	$5022
B_2	28	Quantities	387	270	420	102		60	260	64	1500		6.04 ft.			
		Unit	$5.00	3½¢	$1.20	$5.00		$1.20	$1.50	$8.00	$0.25		$61.00		5%	
		Cost	$1935	$9	$504	$510	0	$72	$390	$512	$375	$50	$368	$4725	$236	$4961
	36	Quantities	696	270	628	142		75	400	108	3100		8.38 ft.			
		Unit	$5.00	3½¢	$1.20	$5.00		$1.20	$1.50	$8.00	$0.25		$61.00		5%	
		Cost	$3480	$9	$754	$710	0	$90	$600	$864	$775	$50	$511	$7843	$392	$8235
B_3	12	Quantities	74	0	125	31	0	0	60	0	60		0			
		Unit	$5.00		$1.20	$5.00			$1.50		$0.25		0		5%	
		Cost	$370		$150	$155			$90		$15	$100	0	$880	$44	$924
	20	Quantities	229	0	285	59	0	0	115	0	350		.85 ft.			
		Unit	$5.00		$1.20	$5.00			$1.50		$0.25		$61.00		5%	
		Cost	$1145		$342	$295			$173		$63	$200	$52	$2270	$113	$2383
	28	Quantities	496	0	450	103	0	0	210	0	525		1.52 ft.			
		Unit	$5.00		$1.20	$5.00			$1.50		$0.25		$61.00	$4374	5%	
		Cost	$2480		$540	$515			$315		$131	$300	$93		$219	$4593
	36	Quantities	880	0	780	137	0	0	290	0	1075		2.27 ft.			
		Unit	$5.00		$1.20	$5.00			$1.50		$0.25		$61.00		5%	
		Cost	$4400		$936	$685			$435		$269	$400	$139	$7264	$363	$7627

Estimate of Quantities and Costs

	Height in Ft.	Item	Neatwork			Footings			Cu. Yds. of Excavation	Piles	Cu.Yds. of Fill	Falsework	Change in Length of Bridge One Abutment	Engng.& Incidentals	Grand Total
			Cu. Yds. of Conc.	Lbs. of Steel	Sq. Yds. of Forms	Cu. Yds. of Conc.	Lbs. of Steel	Sq. Yds. of Forms							
B_5	12	Quantities	26	540	64	26	0	0	45	0	76		10 ft.		
		Unit	$5.00	3½¢	$1.20	$5.00			$1.50		$0.25		$61.00	5%	
		Cost	$130	$19	$77	$130			$68		$19	0	$610	$53	$1106
	20	Quantities	52	540	96	25	0	0	48	27	400		22 ft.		
		Unit	$5.00	3½¢	$1.20	$5.00			$1.50	$8.00	$0.25		$61.00	5%	
		Cost	$260	$19	$115	$125			$72	$216	$100	0	$1340	$112	$2359
	28	Quantities	80	945	134	25	0	0	46	32	960		34 ft.		
		Unit	$5.00	3½¢	$1.20	$5.00			$1.50	$8.00	$0.25		$61.00	5%	
		Cost	$400	$33	$161	$125			$69	$256	$240	$45	$2075	$170	$3574
	36	Quantities	103	945	172	36	550	0	68	45	1860		46 ft.		
		Unit	$5.00	3½¢	$1.20	$5.00	3½¢		$1.50	$8.00	$0.25		$61.00	5%	
		Cost	$515	$33	$206	$180	$19		$102	$360	$465	$60	$2800	$237	$4977
B_6	12	Quantities	32	435	74	30	275	0	50	0	70		7.6 ft.		
		Unit	$5.00	3½¢	$1.20	$5.00	3½¢		$1.50		$0.25		$61.00	5%	
		Cost	$160	$15	$69	$150	$10		$75		$18	0	$460	$49	$1026
	20	Quantities	58	480	103	24	0	0	45	28	400		19.6 ft.		
		Unit	$5.00	3½¢	$1.30	$5.00			$1.50	$8.00	$0.25		$61.00	5%	
		Cost	$290	$17	$124	$120			$68	$224	$100	0	$1200	$107	$2250
	28	Quantities	97	480	154	29	0	0	53	35	935		31.6 ft.		
		Unit	$5.00	3½¢	$1.20	$5.00			$1.50	$8.00	$0.25		$61.00	5%	
		Cost	$485	$17	$185	$145			$80	$280	$234	$45	$1930	$170	$3571
	36	Quantities	148	385	200	49	1090	0	70	54	1800		43.6 ft.		
		Unit	$5.00	3½¢	$1.20	$5.00	3½¢		$1.50	$8.00	$0.25		$61.00	5%	
		Cost	$740	$13	$240	$245	$38		$105	$432	$450	$60	$2660	$249	$5232

FIG. 43b.

Estimate of Quantities and Costs

	Height in Ft.	Item	Neatwork			Footings			Cu. Yds. of Excavation	Piles	Cu.Yds. of Fill	Falsework	Change in Length of Bridge One Abutment	Engng.& Incidentals	Grand Total
			Cu. Yds. of Conc.	Lbs. of Steel	Sq. Yds. of Forms	Cu. Yds. of Conc.	Lbs. of Steel	Sq. Yds. of Forms							
B_7	12	Quantities	27	745	71	15	730	0	25	19	76		8.2 ft.		
		Unit	$5.50	3½¢	$1.20	$6.50	3½¢		$1.50	$8.00	$0.25		$61.00	5%	
		Cost	$149	$26	$85	$98	$26		$38	$152	$19	0	$500	$55	$1148
	20	Quantities	45	781	97	19	985	0	32	27	420		20.2 ft.		
		Unit	$5.50	3½¢	$1.20	$6.50	3½¢		$1.50	$8.00	$0.25		$61.00	5%	
		Cost	$248	$27	$116	$123	$34		$48	$216	$105	0	$1230	$107	$2254
	28	Quantities	67	1050	137	24	1040	0	46	33	970		32.2 ft.		
		Unit	$5.50	3½¢	$1.20	$6.50	3½¢		$1.50	$8.00	$0.25		$61.00	5%	
		Cost	$369	$37	$164	$156	$36		$69	$264	$243	$45	$1960	$167	$3510
	36	Quantities	88	1210	174	29	1250	0	58	43	1900		44.2 ft.		
		Unit	$5.50	3½¢	$1.20	$6.50	3½¢		$1.50	$8.00	$0.25		$61.00	5%	
		Cost	$484	$42	$209	$189	$44		$87	$344	$475	$60	$2700	$232	$4866
B_8	12	Quantities	25	480	65	15	610	0	27	19	76	0	8.2 ft.		
		Unit	$6.50	3½¢	$1.20	$6.50	3½¢		$1.50	$8.00	$0.25		$61.00	5%	
		Cost	$163	$17	$78	$98	$21		$41	$152	$19		$500	$54	$1143
	20	Quantities	25	480	65	15	610	20	3	19	425		20.2 ft.		
		Unit	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20	$1.50	$8.00	$0.25		$61.00	5%	
		Cost	$163	$17	$78	$98	$21	$24	$4	$152	$106	0	$1230	$95	$1988
	28	Quantities	25	480	65	15	610	31	0	21	1010		32.2 ft.		
		Unit	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20		$12.50	$0.25		$61.00	5%	
		Cost	$163	$17	$78	$98	$21	$38		$263	$253	$45	$1960	$147	$3083
	36	Quantities	25	480	65	18	610	35	0	21	1975		44.2 ft.		
		Unit	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20		$15.00	$0.25		$61.00	5%	
		Cost	$163	$17	$78	$117	$21	$42		$315	$494	$60	$2700	$200	$4207

FIG. 43c.

Estimate of Quantities and Costs

	Height in Ft.	Item	Neatwork			Footings			Cu.Yds. of Exc.	Piles	Cu.Yds. of Fill	Falne-work	Engng. and Inci-dentals	Grand Total
			Cu. Yds. of Conc.	Lbs. of Steel	Sq. Yds. of Forms	Cu. Yds. of Conc.	Lbs. of Steel	Sq. Yds. of Forms						
C_1	12	Quant-ities	38	680	120	24	700	32	79	0	171	0		
		Unit	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20	$1.50		$0.25		12%	
		Cost	$247	$24	$144	$156	$25	$38	$119		$43		$96	$892
	20	Quant-ities	100	5050	316	45	2380	48	182	0	630	0		
		Unit	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20	$1.50		$0.25		12%	
		Cost	$650	$177	$379	$293	$83	$58	273		$158		$249	$2320
	28	Quant-ities	183	9950	608	113	7754	80	358	85	1702	0		
		Unit	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20	$1.50	$8.00	$0.25		12%	
		Cost	$1190	$348	$730	$735	$271	$96	$537	$680	$426		$602	$5615
	36	Quant-ities	306	16600	1007	176	12070	86	602	141	3450	0		
		Unit	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20	$1.50	$8.00	$0.25		12%	
		Cost	$1989	$581	$1208	$1144	$422	$103	$903	$1128	$862		$1001	$9341
C_2	12	Quant-ities	37	2440	134	10	200	14	30	0	80			
		Unit	$6.50	3½¢	$1.20	$5.00	3½¢	$1.20	$1.50		$0.25		8%	
		Cost	$241	$85	$161	$50	$7	$17	$45		$20	$10	$51	$ 687
	20	Quant-ities	102	6730	349	20	900	34	65	0	300			
		Unit	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20	$1.50		$0.25		8%	
		Cost	$663	$236	$419	$130	$32	$41	$98		$75	$20	$137	$1851
	28	Quant-ities	189	12130	602	37	1180	41	130	0	630			
		Unit	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20	$1.50		$0.25		8%	
		Cost	$1229	$425	$722	$241	$41	$49	$195		$158	$30	$247	$3337
	36	Quant-ities	304	20000	1015	42	840	74	140	54	1200			
		Unit	$6.50	3½¢	$1.20	$5.00	3½¢	$1.20	$1.50	$8.00	$0.25		8%	
		Cost	$1976	$700	$1218	$210	$29	89	$210	$432	$300	$30	$416	$5610

Fig. 43d.

Estimate of Quantities and Costs

	Height in Ft.	Item	Floor			Headwork			Footings			Cu. Yds. of Excavation	Piles	Cu. Yds. of Fill	Falsework	Change in Length of Bridge One Abutment	Engng. and Incidentals	Grand Total
			Cu. Yds. of Conc.	Lbs. of Steel	Sq. Yds. of Forms	Cu. Yds. of Conc.	Lbs. of Steel	Sq. Yds. of Forms	Cu. Yds. of Conc.	Lbs. of Steel	Sq. Yds. of Forms							
C_3	12	Quantities	0	0	0	29	1875	103	11.5	405	0	25	0	80		40 ft.		
		Unit Cost				$6.50	3½¢	$1.20	$6.50	3½¢		$1.50		$0.25		$61.00	8%	
						$189	$66	$124	$75	$14		$38		$20	$10	$244	$62	$842
	20	Quantities	0	0	0	68	4400	198	18	630	0	36	0	250		10.0 ft.		
		Unit Cost				$6.50	3½¢	$1.20	$6.50	3½¢		$1.50		$0.25		$61.00	8%	
						$ 442	$154	$238	$117	$22		$54		$63	$20	$610	$138	$1858
	28	Quantities	0	0	0	104	67.20	345	29	1020	0	63	0	690		16.0 ft.		
		Unit Cost				$6.50	3½¢	$1.20	$6.50	3½¢		$1.50		$0.25		$61.00	8%	
						$ 676	$235	$414	$189	$36		$95		$173	$30	$976	$226	$3050
	36	Quantities	0	0	0	160	10350	535	29	1000	0	55	42	1300		22.0 ft.		
		Unit Cost				$6.50	3½¢	$1.20	$6.50	3½¢		$1.50	$8.00	$0.25		$61.00	8%	
						$1040	$362	$642	$189	$35		$83	$336	$325	$30	$1340	$351	$4733
C_4	12	Quantities	8	2180	48	31	1950	25 99	16	400	24	60	0	70				
		Unit Cost	$6.50	3½¢	$2.50	$6.50	3½¢	$2.50 $1.20	$5.00	3½¢	$1.20	$1.50		$0.25			10%	
			$52	$76	$120	$202	$68	$65 $119	$80	$14	$29	$90		$18	$20		$95	$1046
	20	Quantities	15	4100	81	69	4340	45 224	31	2110	47	100	0	200				
		Unit Cost	$6.50	3½¢	$2.50	$6.50	3½¢	$2.50 $1.20	$6.50	3½¢	$1.20	$1.50		$0.25			10%	
			$98	$144	$203	$449	$152	$113 $269	$202	$74	$56	$150		$50	$40		$200	$2200
	28	Quantities	21	5370	115	114	7180	100 298	41	2790	65	130	0	550				
		Unit Cost	$6.50	3½¢	$2.50	$6.50	3½¢	$2.50 $1.20	$6.50	3½¢	$1.20	$1.50		$0.25			10%	
			$137	$201	$288	$741	$251	$250 $358	$267	$98	$78	$195		$138	$60		$306	$3368
	36	Quantities	27	7360	148	175	11000	125 554	68	1500	94	220	62	1050				
		Unit Cost	$6.50	3½¢	$2.50	$6.50	3½¢	$2.50 $1.20	$5.00	3½¢	$1.20	$1.50	$8.00	$0.25			10%	
			$176	$258	$370	$1138	$385	$313 $641	$340	$53	$113	$330	$496	$262	$60		$493	$5428

FIG. 43e.

Estimate of Quantities and Costs

	Height in Ft.	Item	Floor			Neatwork			Footings			Cu. Yds. of Excavation	Piles	Cu. Yds. of Fill	Falsework	Change in Length of Bridge One Abutment	Engng. & Incidentals	Grand Total
			Cu. Yds. of Conc.	Lbs. of Steel	Sq. Yds. of Forms	Cu. Yds. of Conc.	Lbs. of Steel	Sq. Yds. of Forms	Cu. Yds. of Conc.	Lbs. of Steel	Sq. Yds. of Forms							
C_5	20	Quantities	30	2740	80	49	2668	130	48	2373	0	67	26	239		3.2 ft.		
		Unit	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20	$6.50	3½¢		$1.50	$8.00	$0.25		$61.00	10%	
		Cost	$195	$96	$96	$319	$93	$156	$312	$83		$101	$208	$60	$100	$140	$196	$2155
	28	Quantities	48	5250	135	90	6873	250	84	7198	0	130	44	550		0.5 ft.		
		Unit	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20	$6.50	3½¢		$1.50	$8.00	$0.25		$61.00	10%	
		Cost	$312	$184	$162	$585	$241	$300	$546	$252		$195	$352	$138	$200	$30	$350	$3847
	36	Quantities	51	5296	140	125	8922	345	113	9852	0	145	52	1050		8.0 ft.		
		Unit	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20	$6.50	3½¢		$1.50	$8.00	$0.25		$61.00	10%	
		Cost	$332	$185	$168	$813	$312	$414	$735	$345		$218	$416	$262	$200	$490	$469	$5379
	44	Quantities	81	7781	200	234	15165	570	153	12254	0	244	80	1912		5.2 ft.		
		Unit	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20	$6.50	3½¢		$1.50	$8.00	$0.25		$61.00	10%	
		Cost	$527	$272	$240	$1521	$531	$684	$995	$429		$366	$640	$478	$300	$320	$730	$8033
C_6	12	Quantities	13	1038	33	33	1084	80	20	890	21	50	0	63				
		Unit	$6.50	3½¢	$2.50	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20	$1.50		$0.25			10%	
		Cost	$85	$36	$83	$215	$38	$96	$130	$31	$25	$75		$16	$10		$84	$ 924
	20	Quantities	23	1835	58	72	2365	177	33	2000	37	83	0	224				
		Unit	$6.50	3½¢	$2.50	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20	$1.50		$0.25			10%	
		Cost	$150	$64	$145	$468	$83	$212	$215	$70	$44	$125		$56	$20		$165	$1817
	28	Quantities	33	2633	84	133	4371	301	50	5066	52	130	0	467				
		Unit	$6.50	3½¢	$2.50	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20	$1.50		$0.25			10%	
		Cost	$215	$92	$210	$865	$153	$361	$325	$177	$62	$195		$117	$30		$280	$3082
	36	Quantities	43	3430	108	208	6840	471	82	8320	82	200	0	1100				
		Unit	$6.50	3½¢	$2.50	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20	$1.50		$0.25			10%	
		Cost	$280	$120	$270	$1352	$239	$565	$533	$291	$98	$300		$250	$30		$433	$4761

FIG. 43f.

Estimate of Quantities and Costs

	Height	Item	Floor			Neatwork			Footings			Cu. Yds. of Exc.	Piles	Cu.Yds. of Fill	False-work	Engng, & Incid-entals	Grand Total
			Cu. Yds. of Conc.	Lbs. of Steel	Sq. Yds. of Forms	Cu. Yds. of Conc.	Lbs. of Steel	Sq. Yds. of Forms	Cu. Yds. of Conc.	Lbs.of Steel	Sq. Yds. of Forms						
C_7	12	Quant-ities	12	2960	54	24	910	76	14	250	18	40	0	60			
		Unit	$6.50	3½¢	$2.50	$6.50	3½¢	$1.20	$5.00	3½¢	$1.20	$1.50		$0.25		8%	
		Cost	$78	$104	$135	$156	$32	$91	$70	$9	$22	$60		$15	0	$62	$834
	20	Quant-ities	21	5170	91	58	2190	186	26	1380	31	70	0	190			
		Unit	$6.50	3½¢	$2.50	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20	$1.50		$0.25		8%	
		Cost	$137	$181	$228	$377	$77	$223	$169	$48	$37	$105		$48	0	$130	$1760
	28	Quant-ities	41	10100	129	87	3290	283	36	1910	37	100	0	500			
		Unit	$6.50	3½¢	$2.50	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20	$1.50		$0.25		8%	
		Cost	$267	$354	$323	$566	$115	$340	$234	$67	$44	$150		$125	0	$207	$2792
	36	Quant-ities	45	11100	166	145	5480	451	61	3240	53	150	0	950			
		Unit	$6.50	3½¢	$2.50	$6.50	3½¢	$1.20	$6.50	3½¢	$1.20	$1.50		$0.25		8%	
		Cost	$293	$389	$415	$943	$192	$541	$397	$113	$64	$225		$238	0	$305	$4115

Fig. 43g.

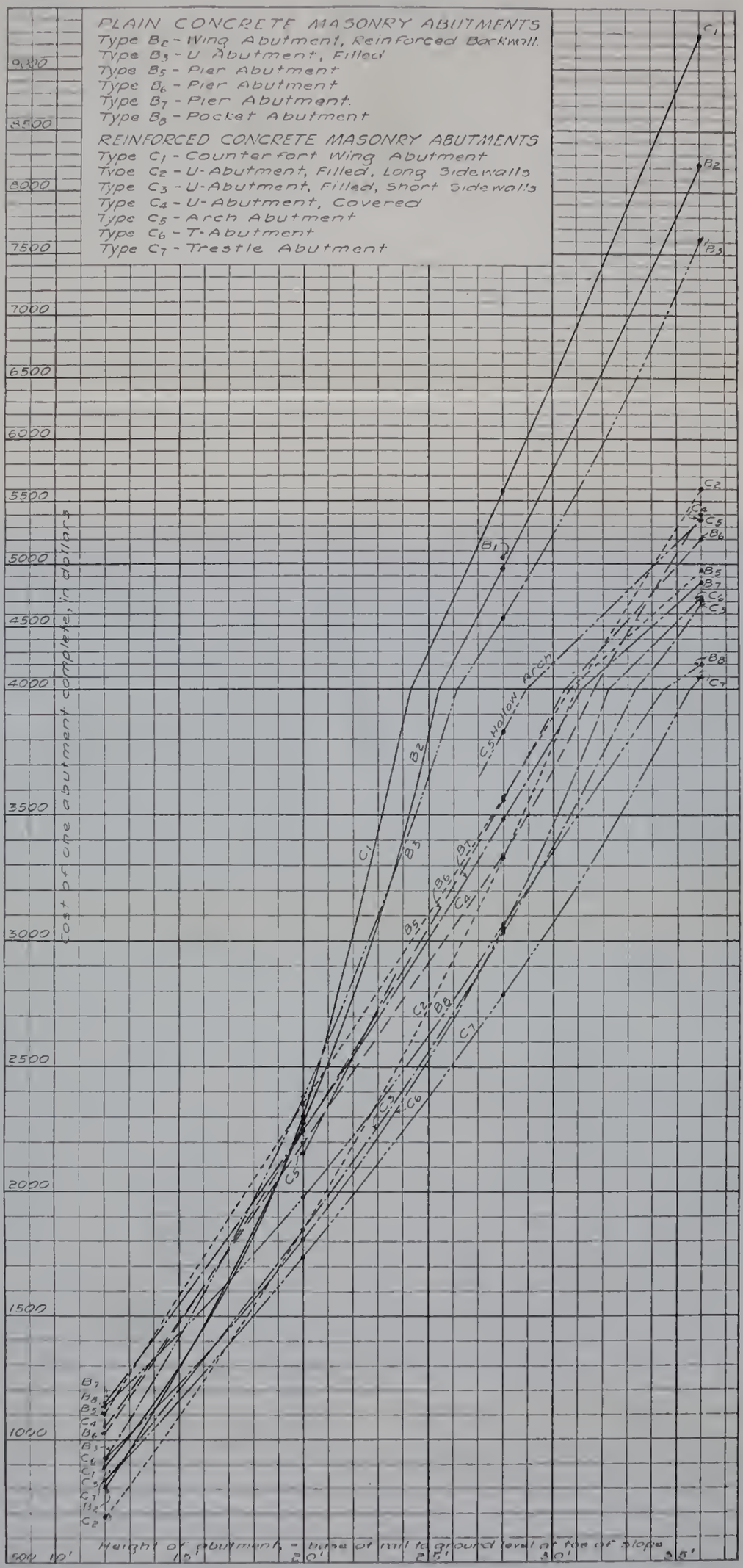


Diagram Showing Total Cost of Abutments of Various Heights

Fig. 44

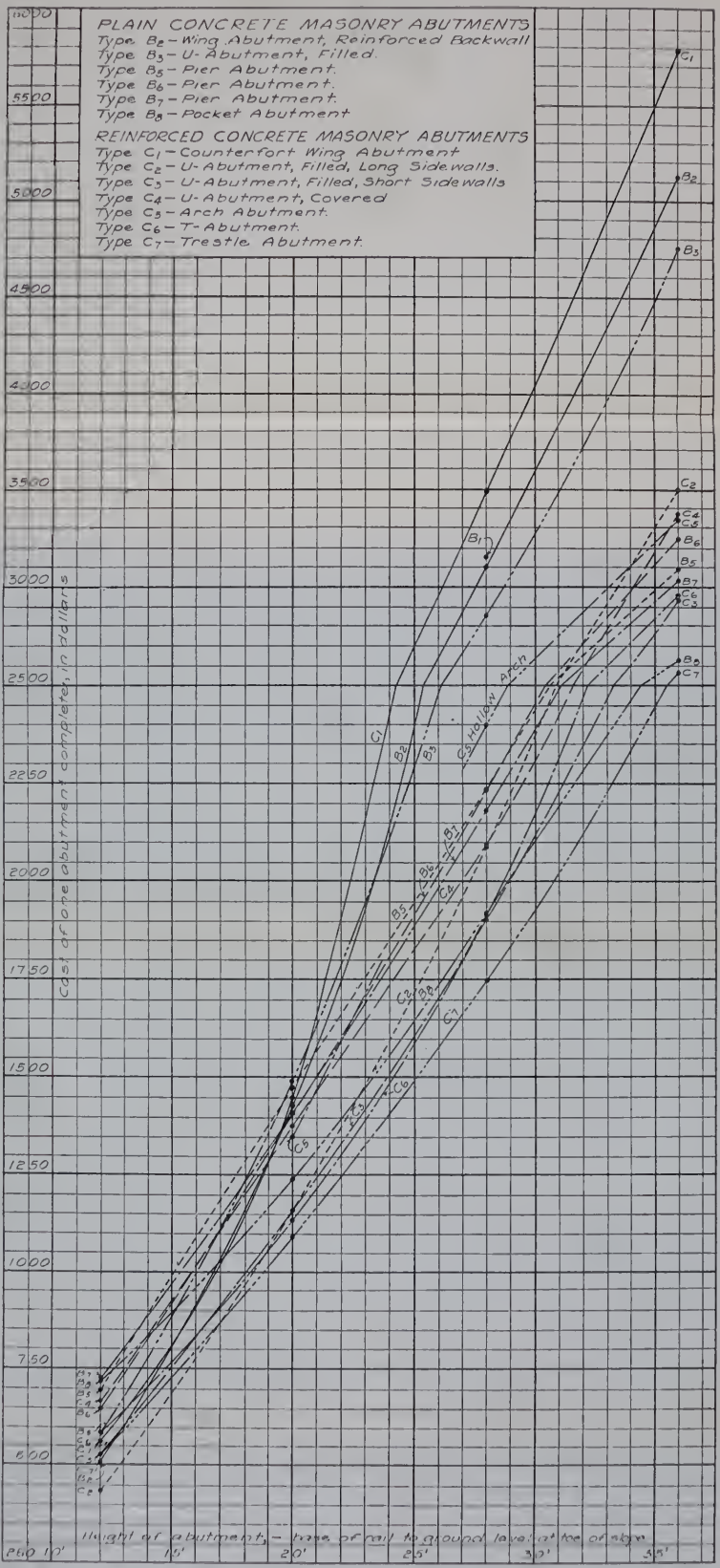


Diagram Showing Total Cost of Abutments of Various Heights
Costs Reduced 37%

Fig. 45

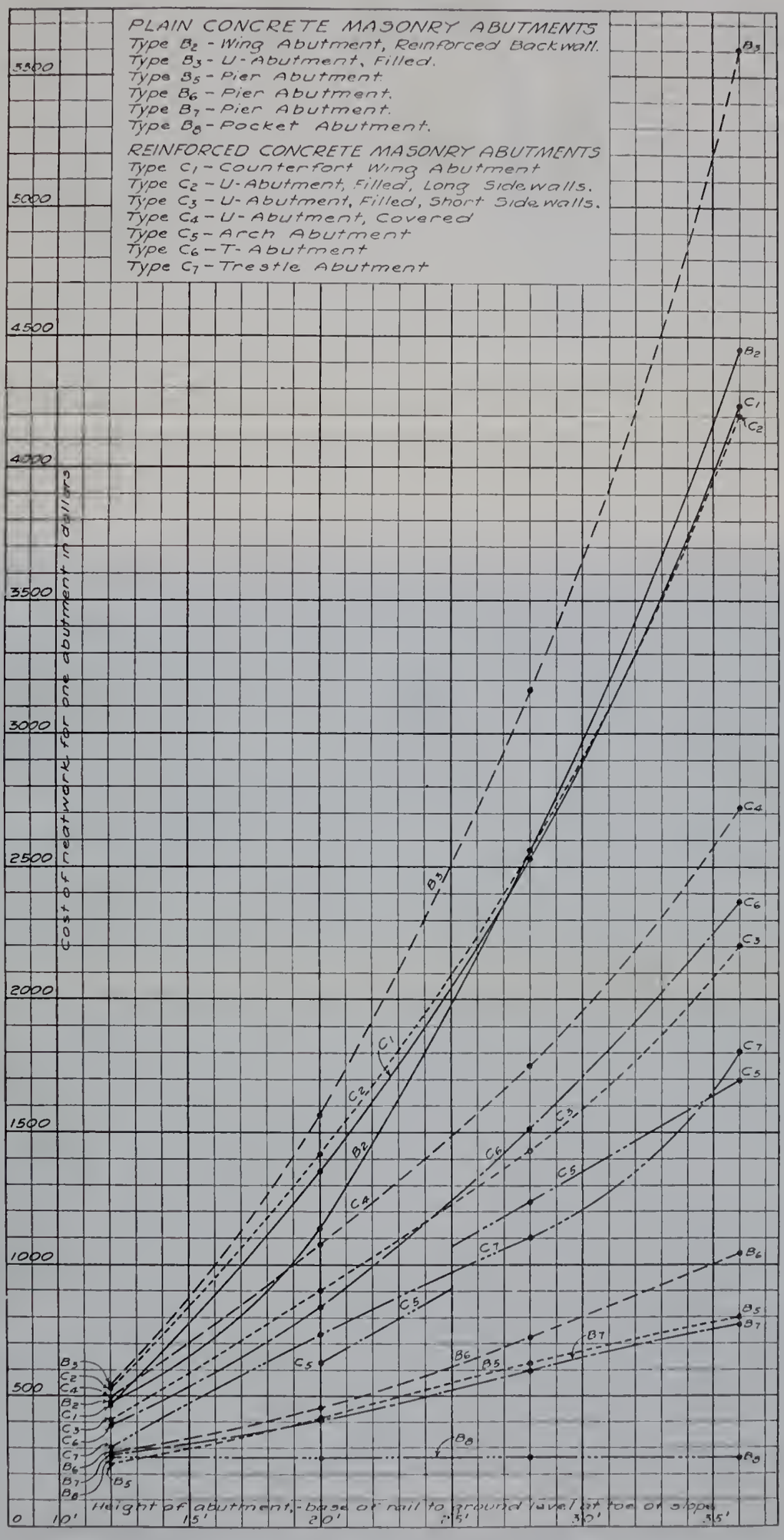


Diagram Showing Cost of Neatwork
of Abutments of Various Heights

Fig. 59

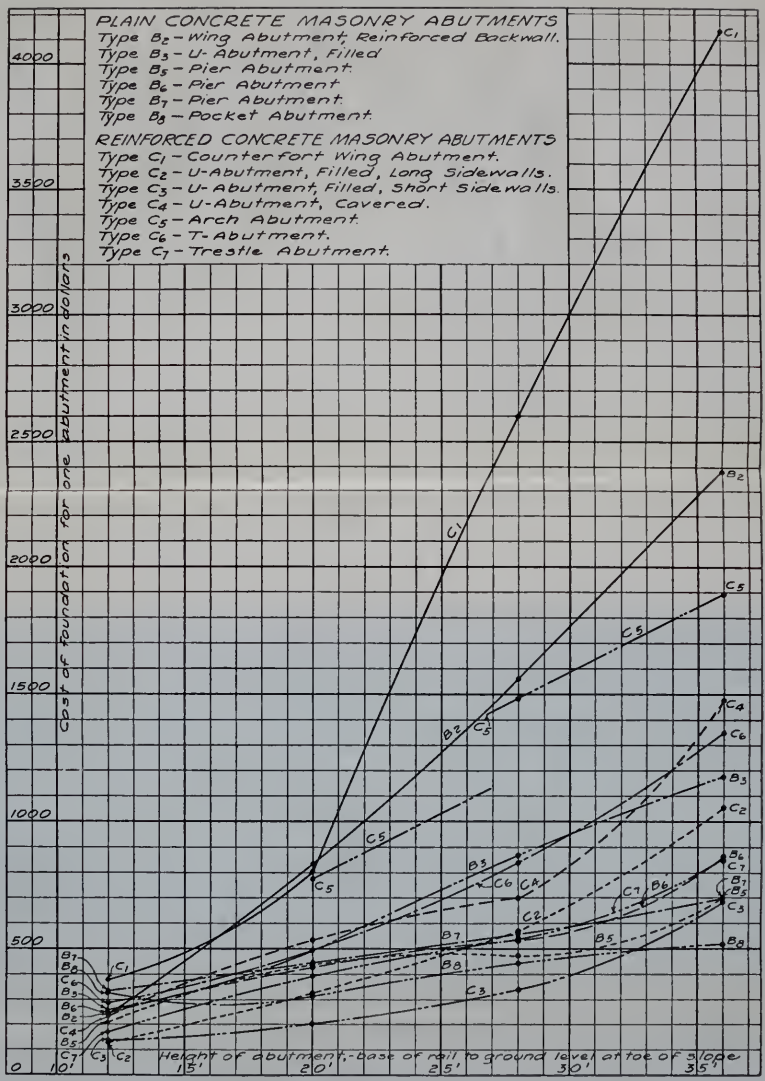


Diagram Showing Cost of Foundation of Abutments of Various Heights

Fig. 60

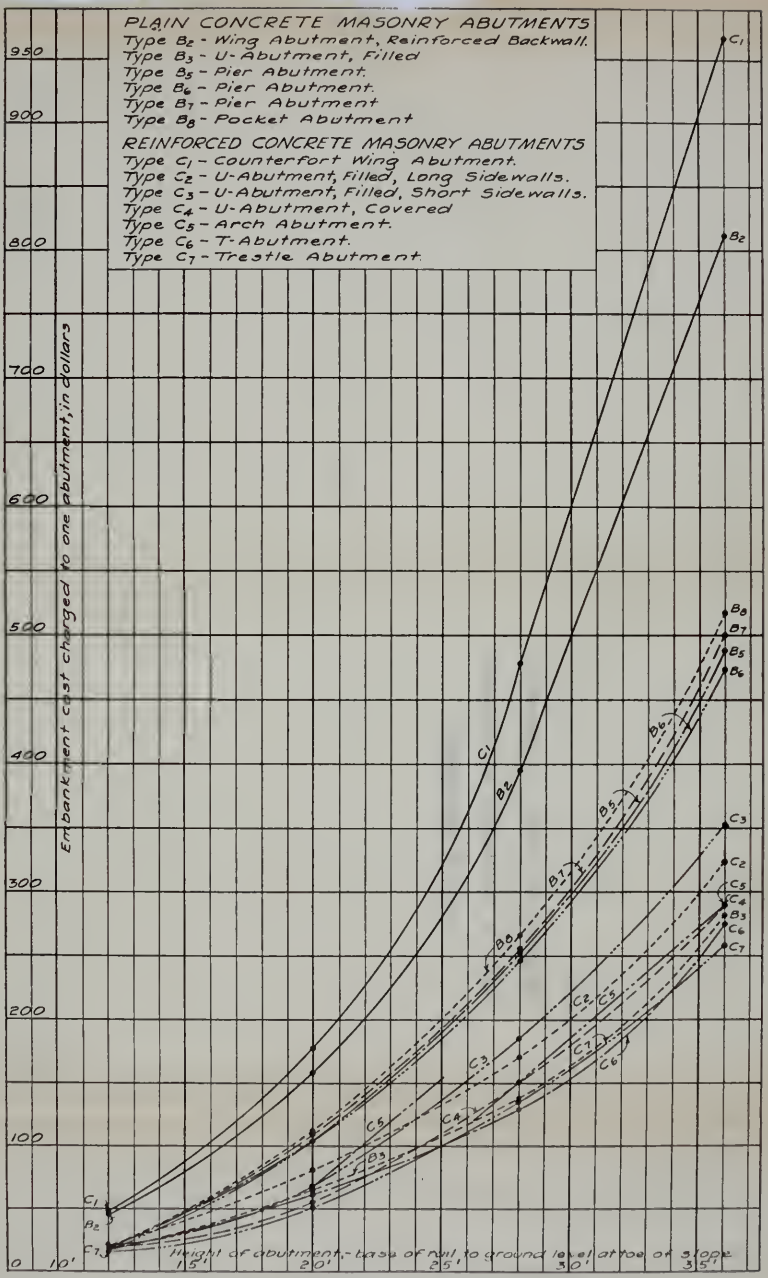
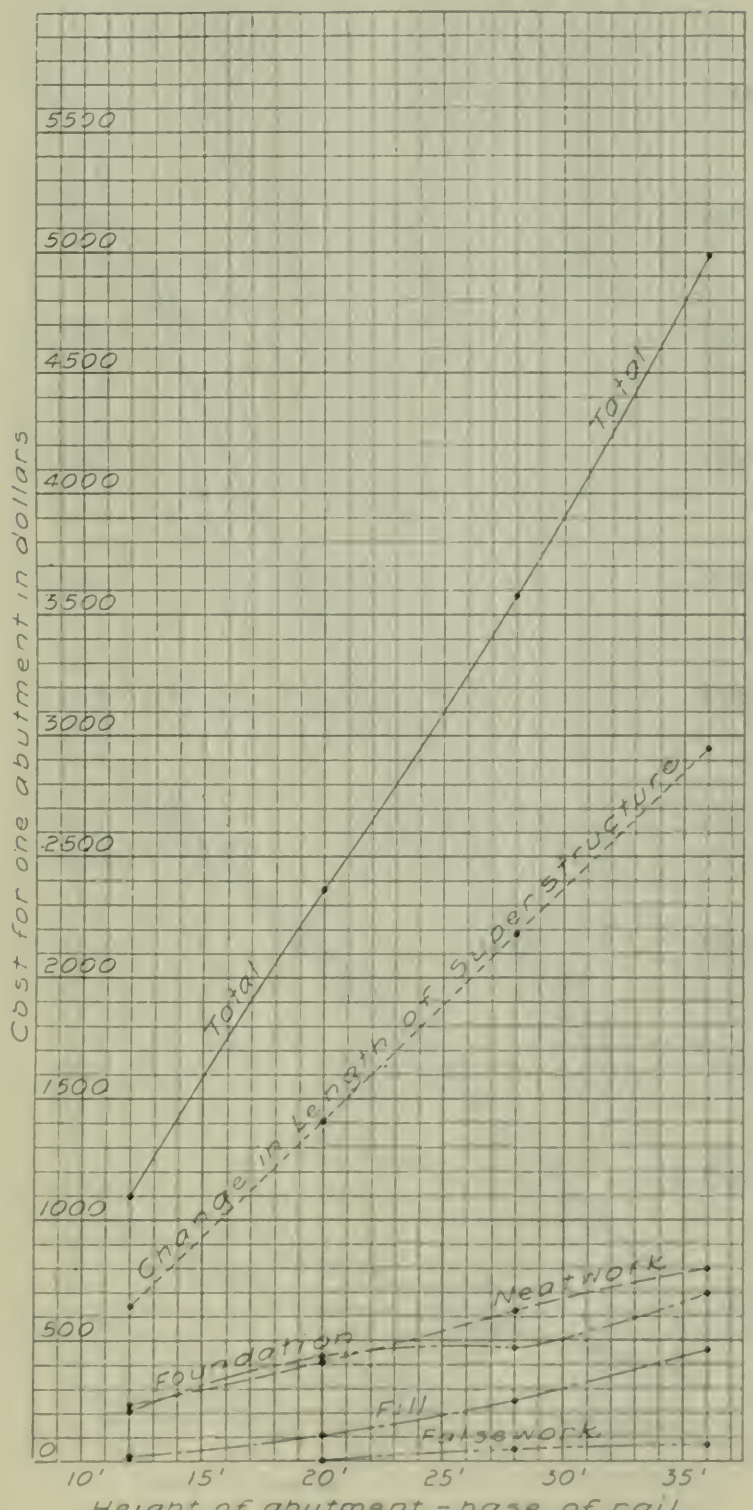


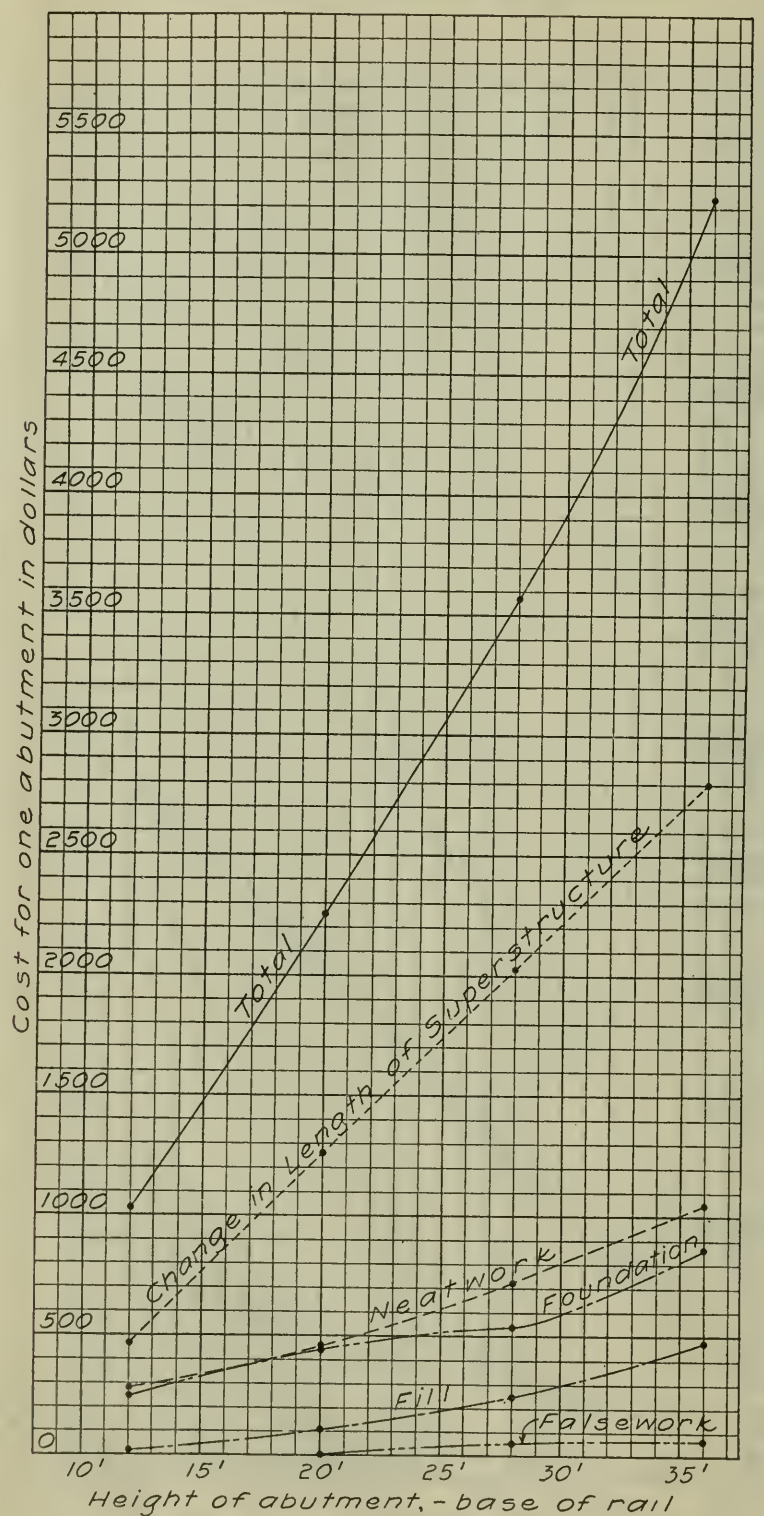
Diagram Showing Cost of Embankment
Charged to Abutments of Various Heights

Fig. 62



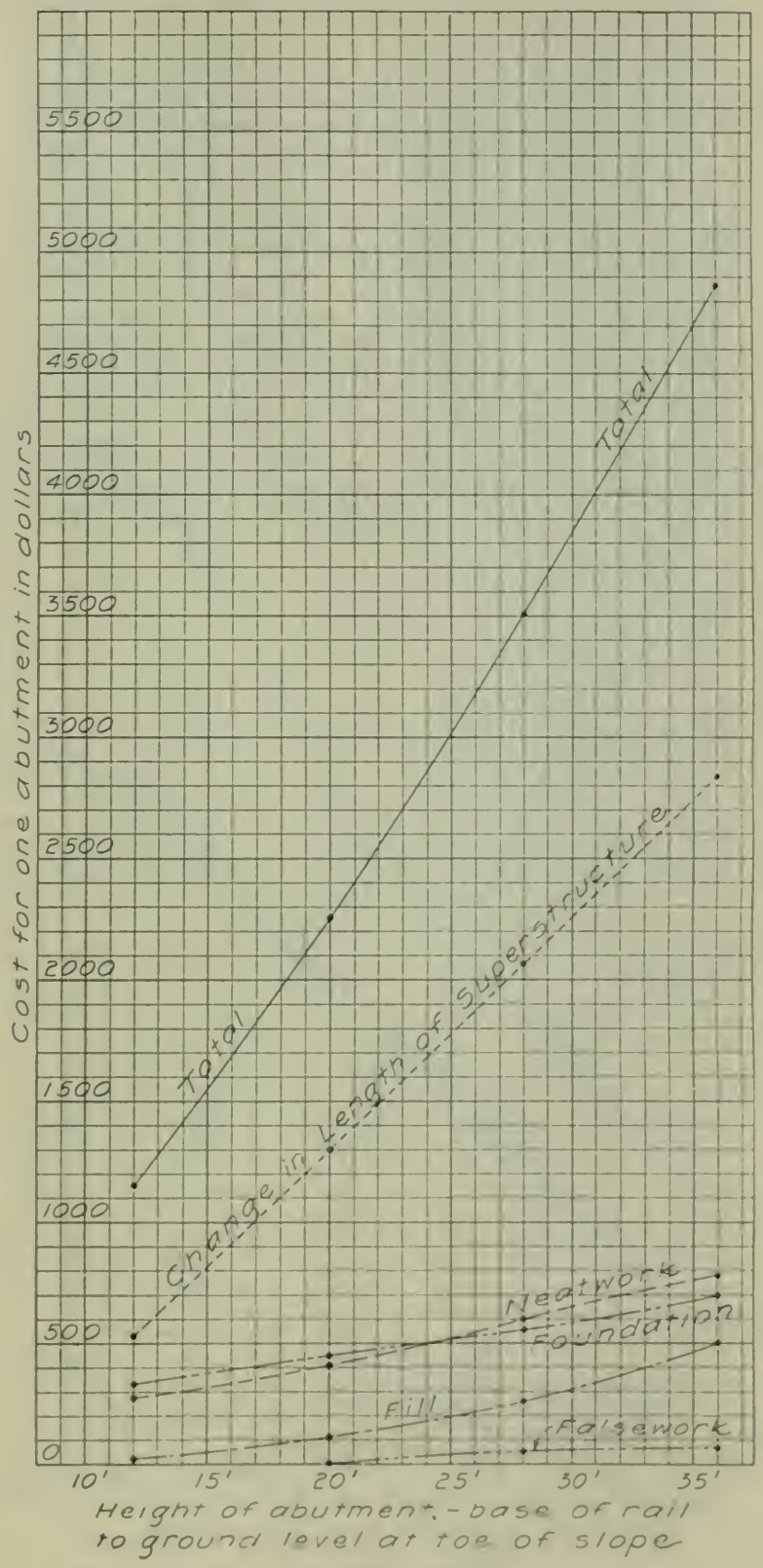
Type B_5

Fig. 48



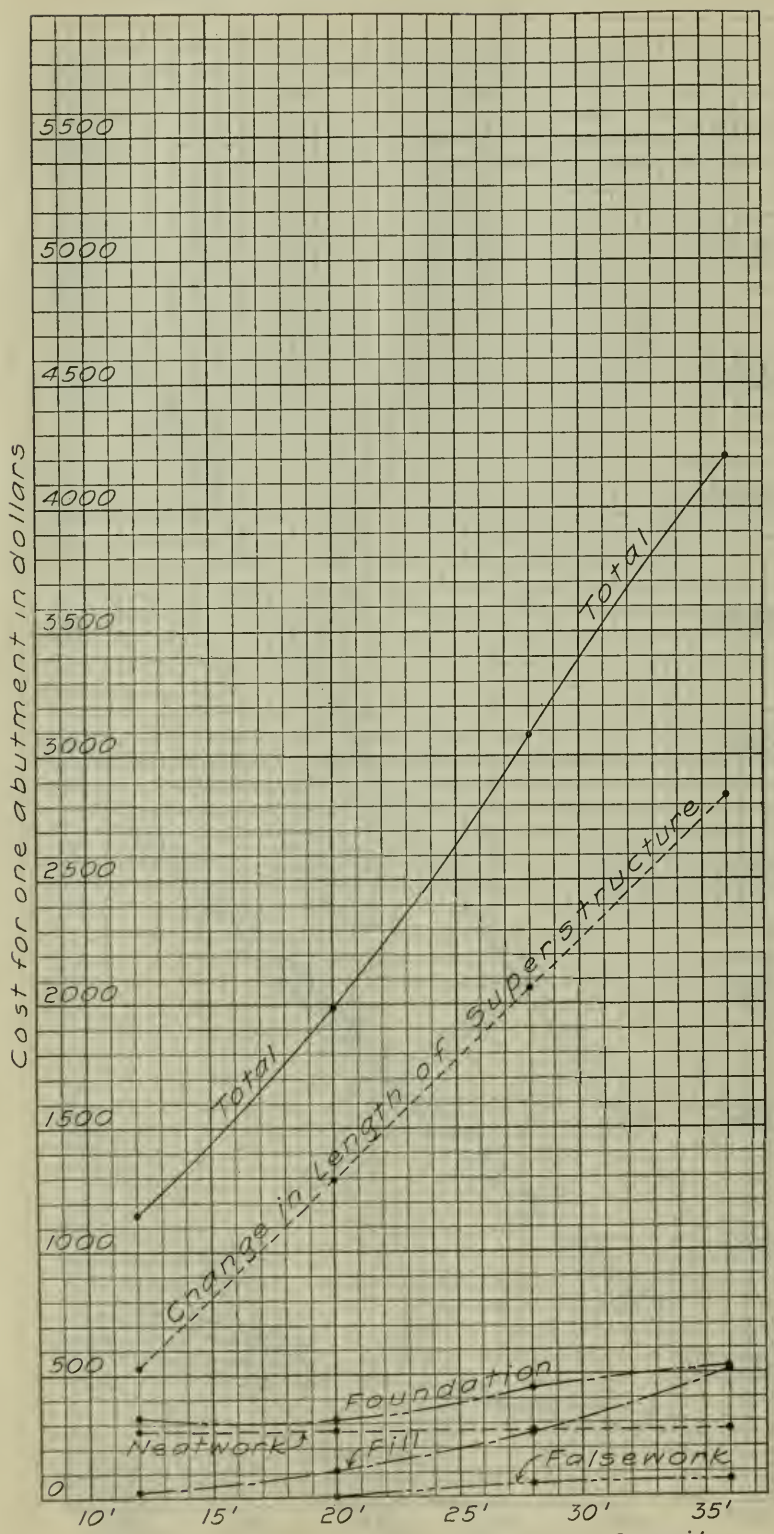
Type B_6

Fig. 49



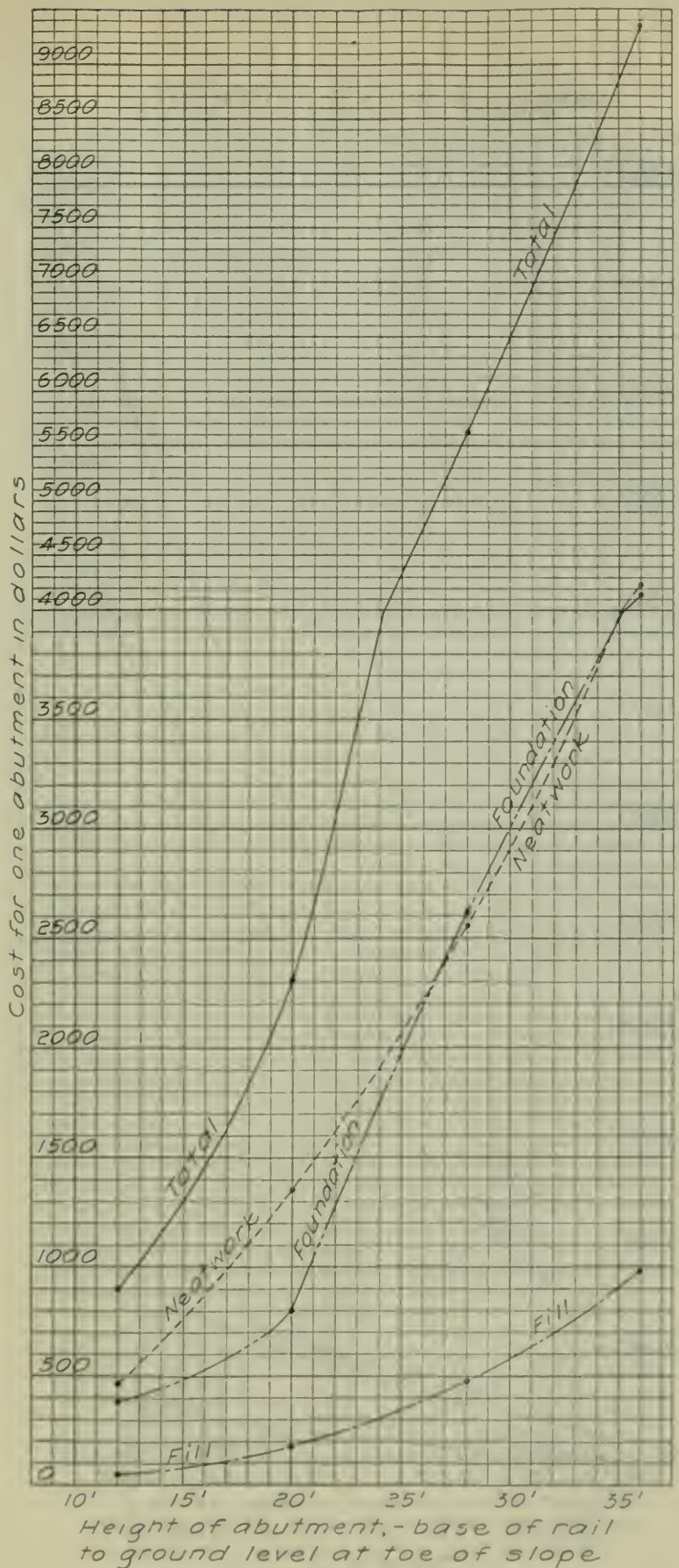
Type B_7

Fig. 50



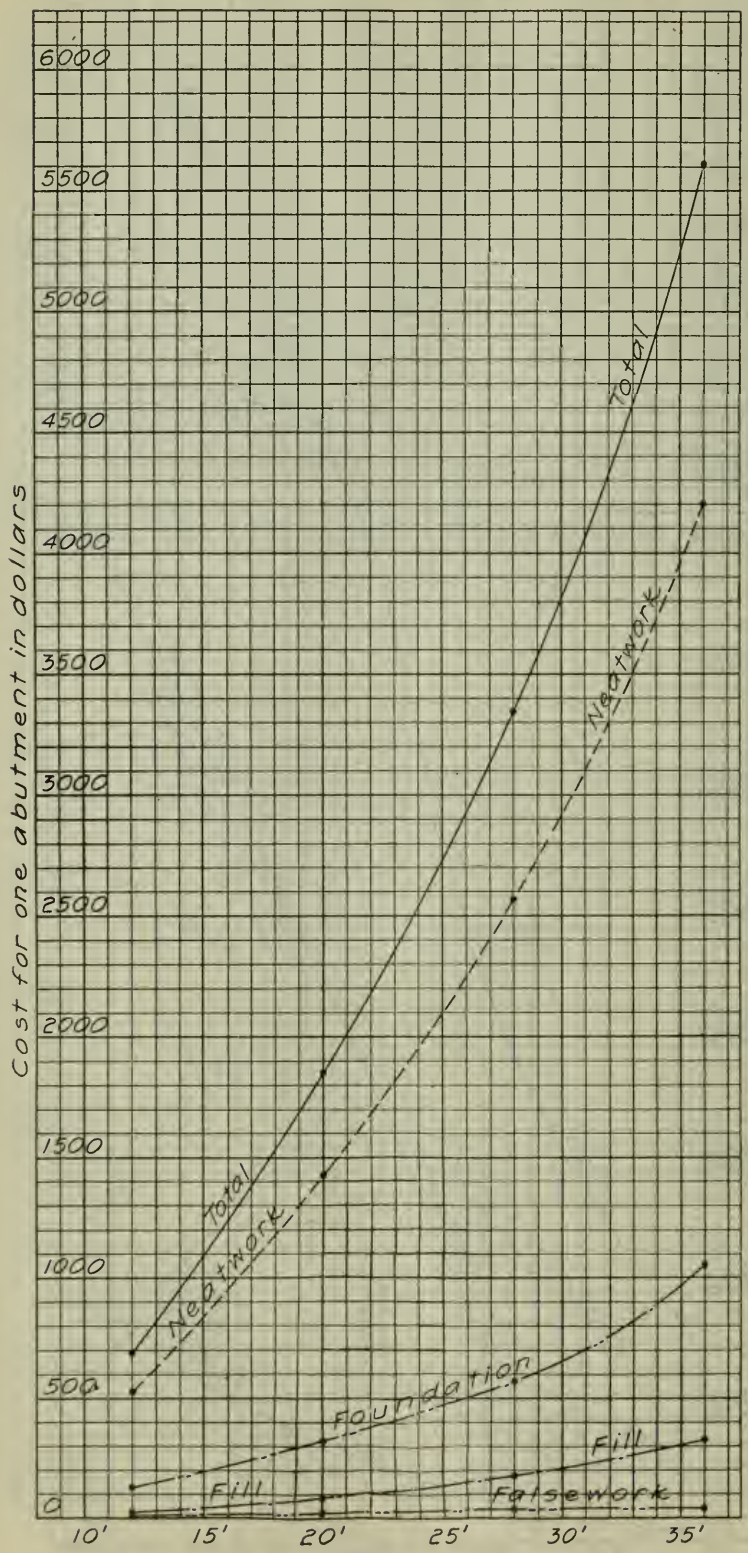
Type B_8

Fig. 51



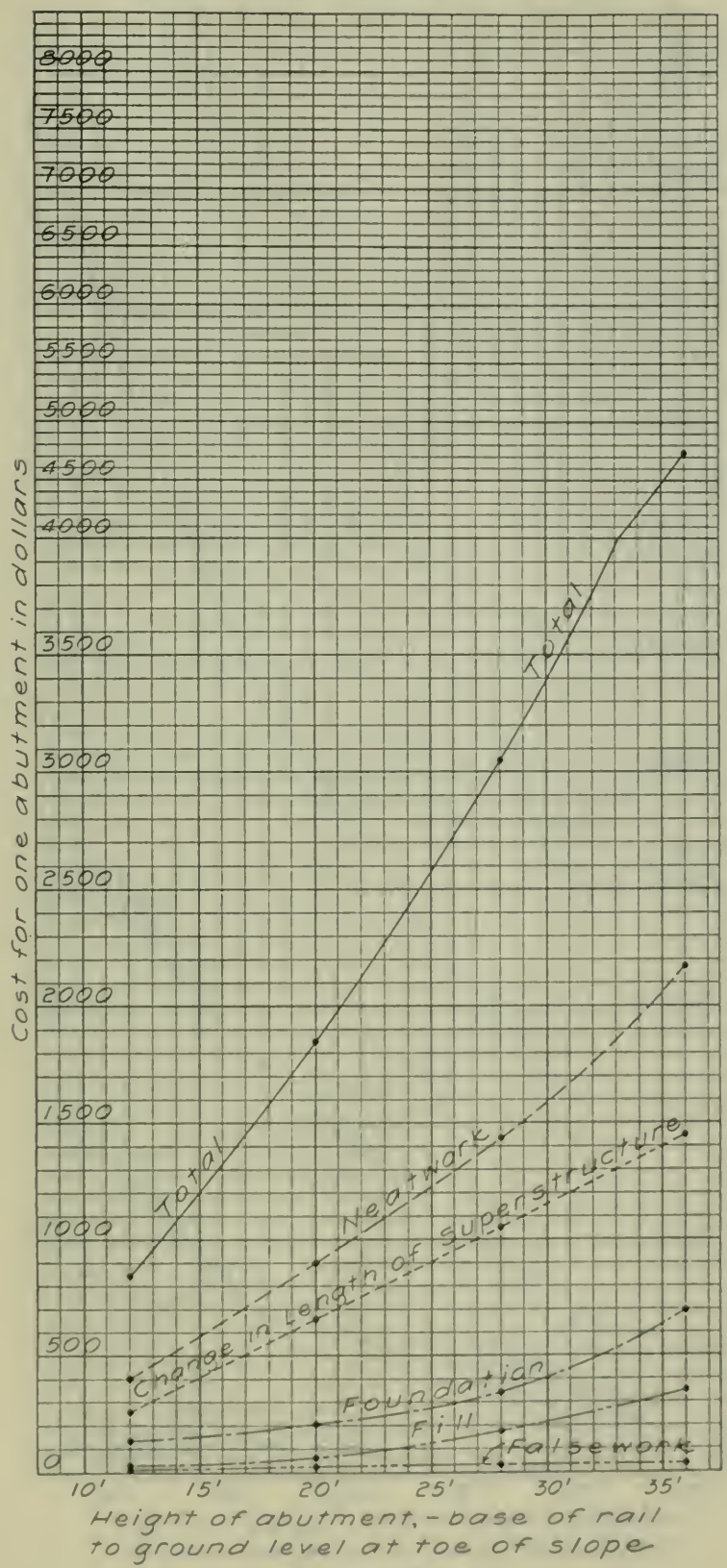
Type C1

Fig. 52



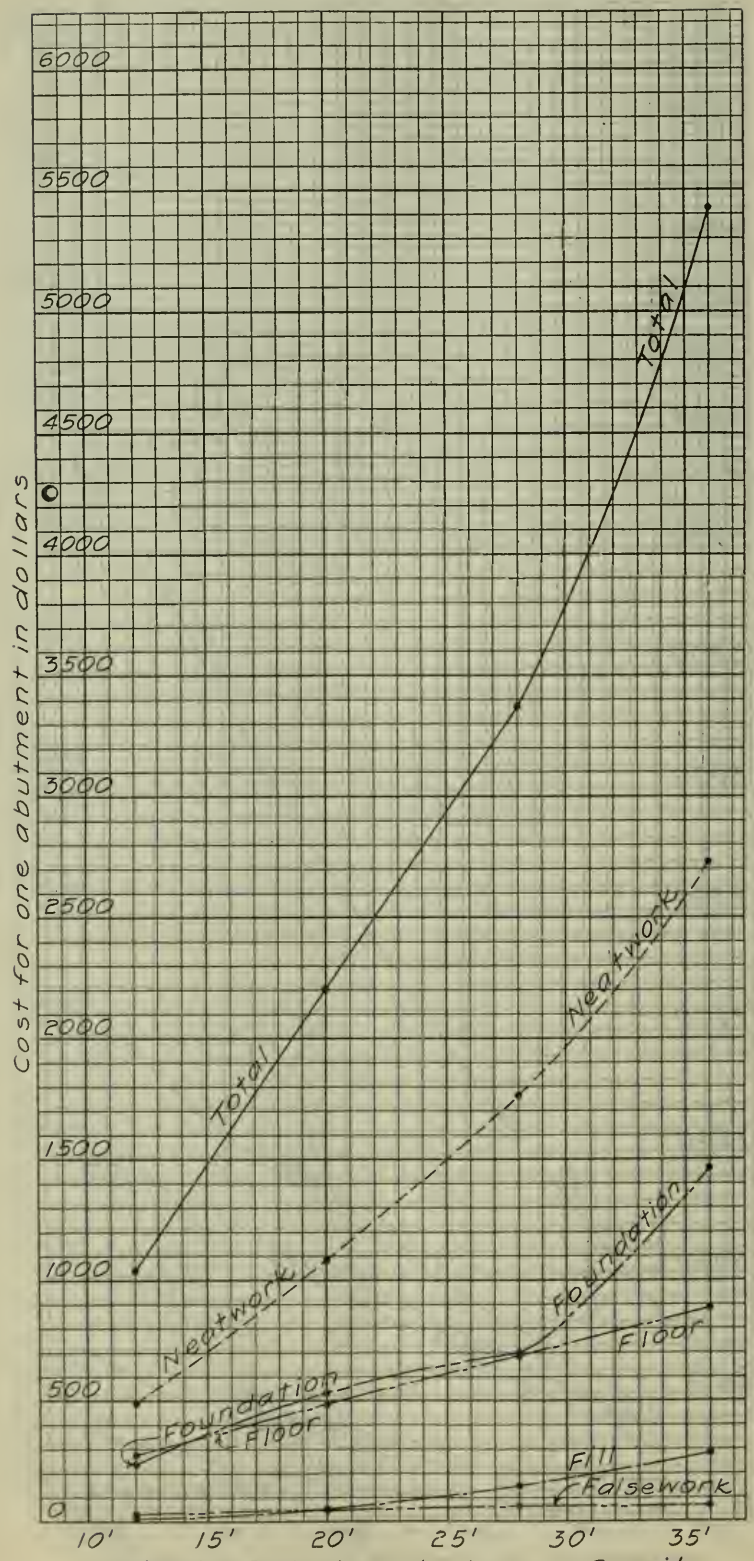
Type C_2

Fig. 53



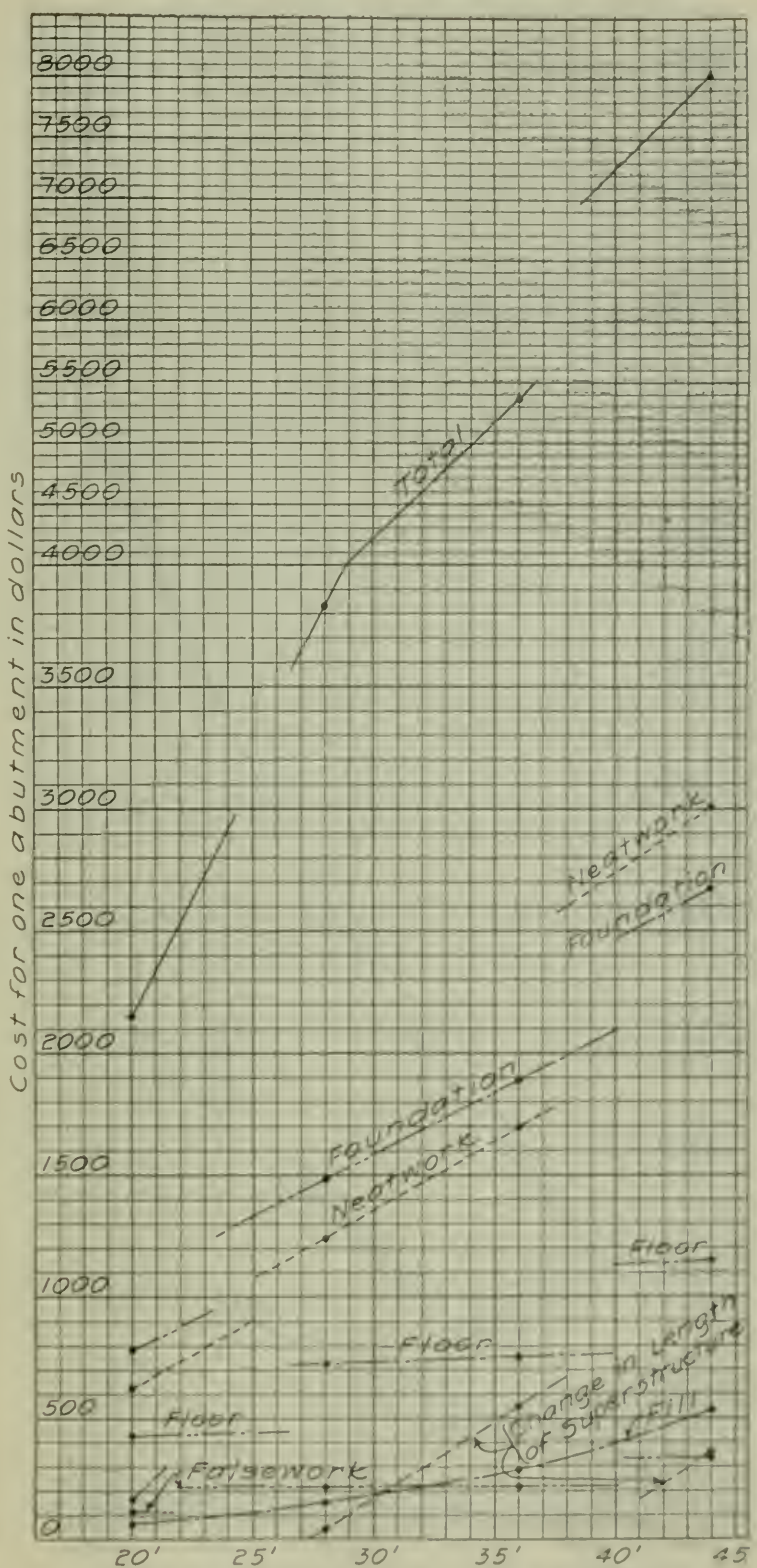
Type C_3

Fig. 54



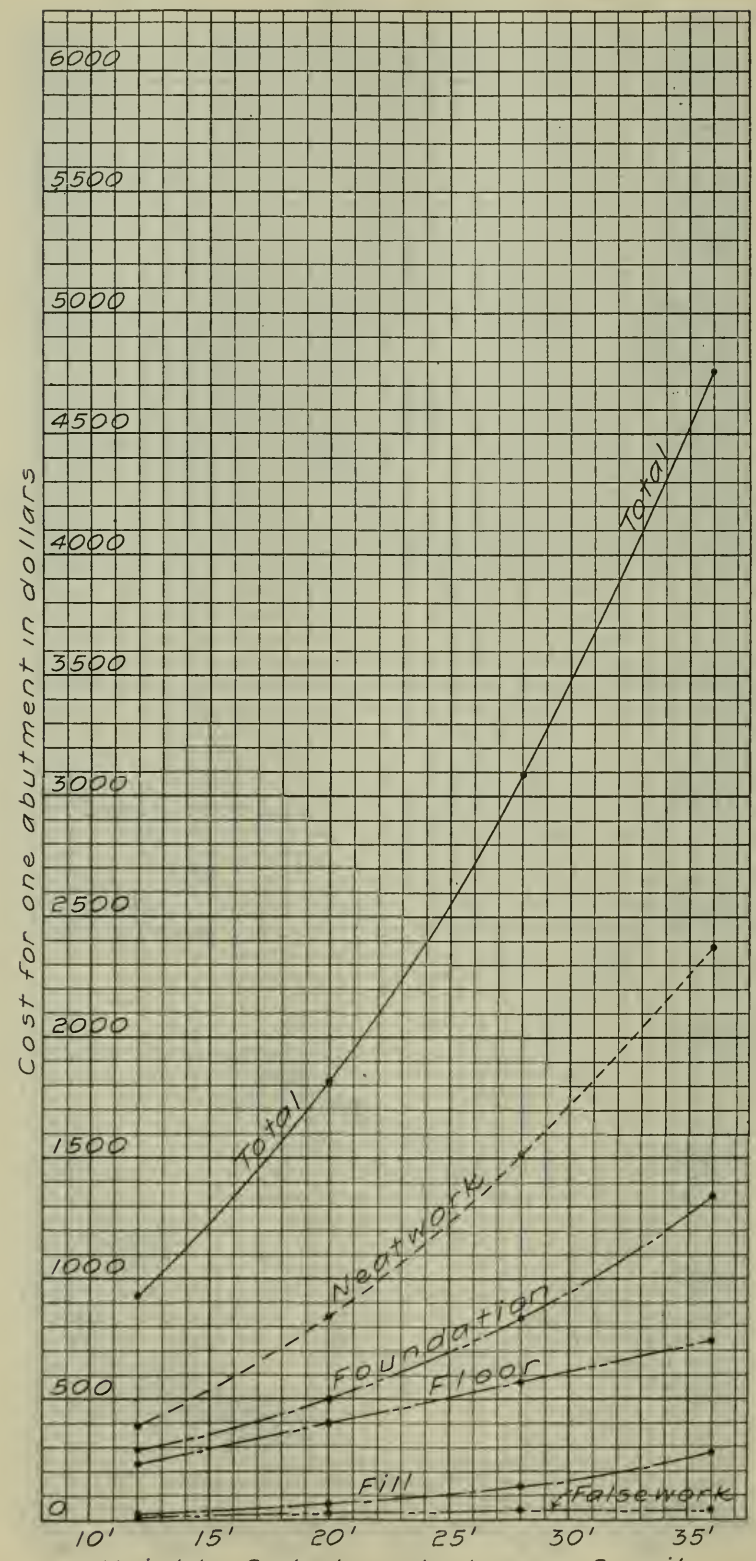
Type C_4

Fig. 55



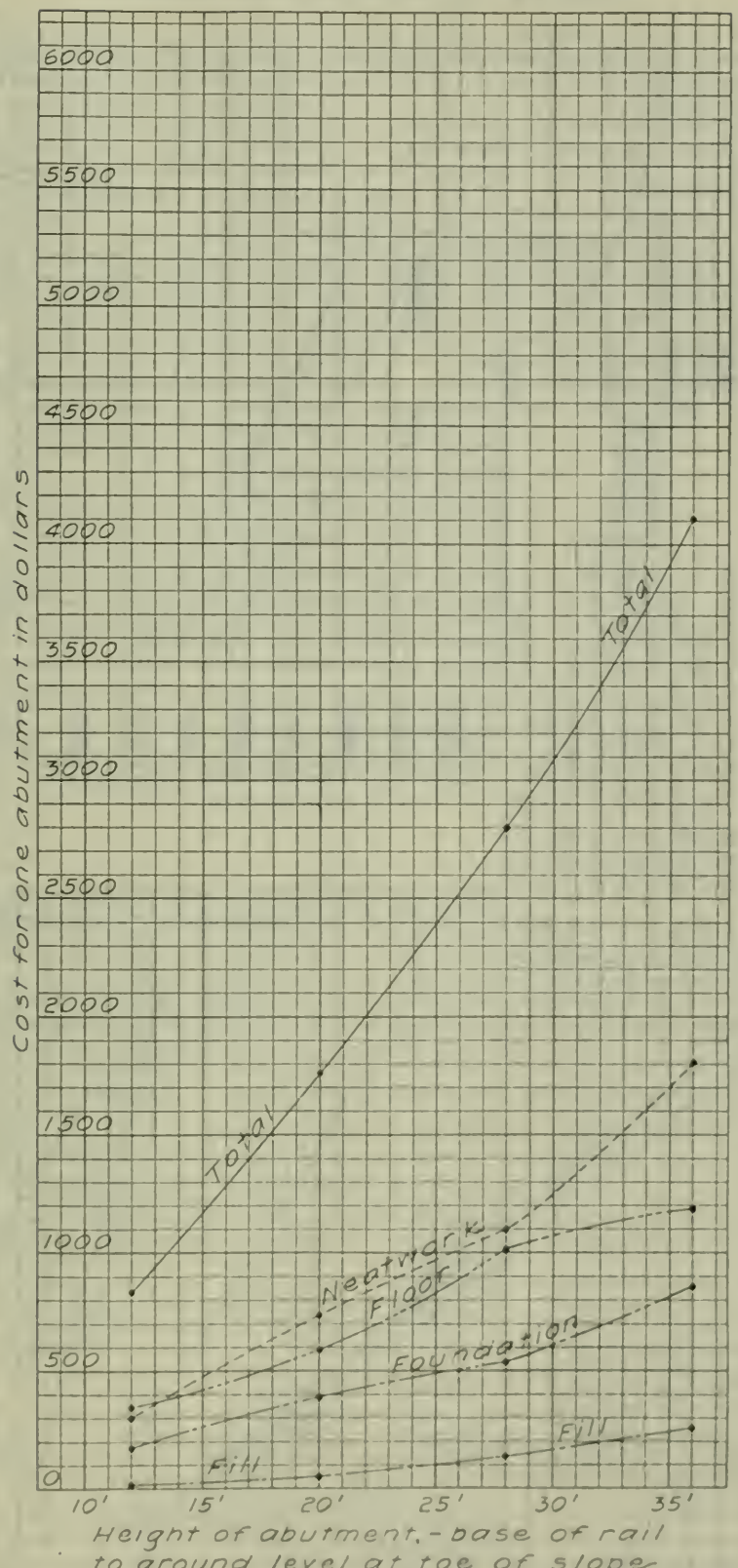
Type C_5

Fig. 56



Type C_6

Fig. 57



Type C_7

Fig. 58

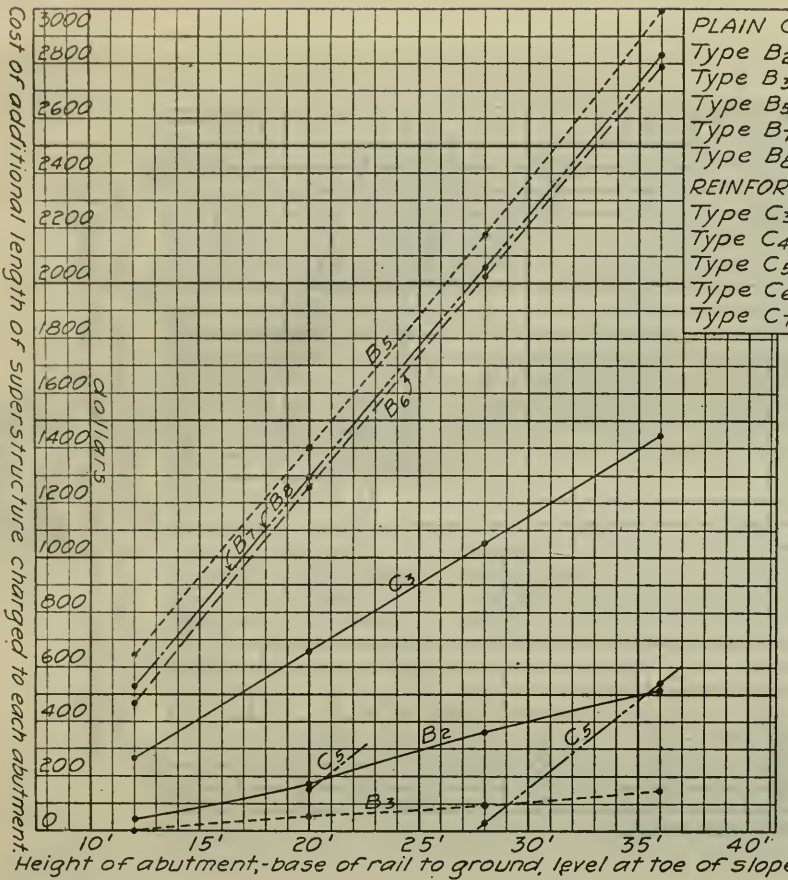


Diagram Showing Cost of Additional Length of Superstructure Charged to Abutments of Various Heights

Fig. 63

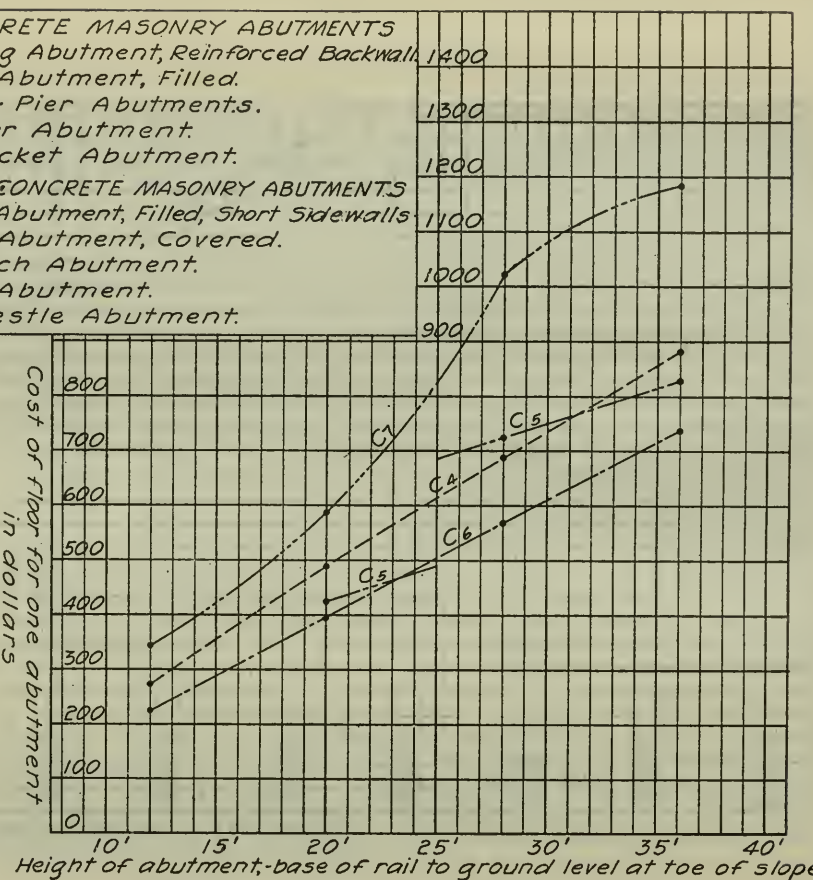


Diagram Showing Cost of Floor for Abutments of Various Heights

Fig. 61

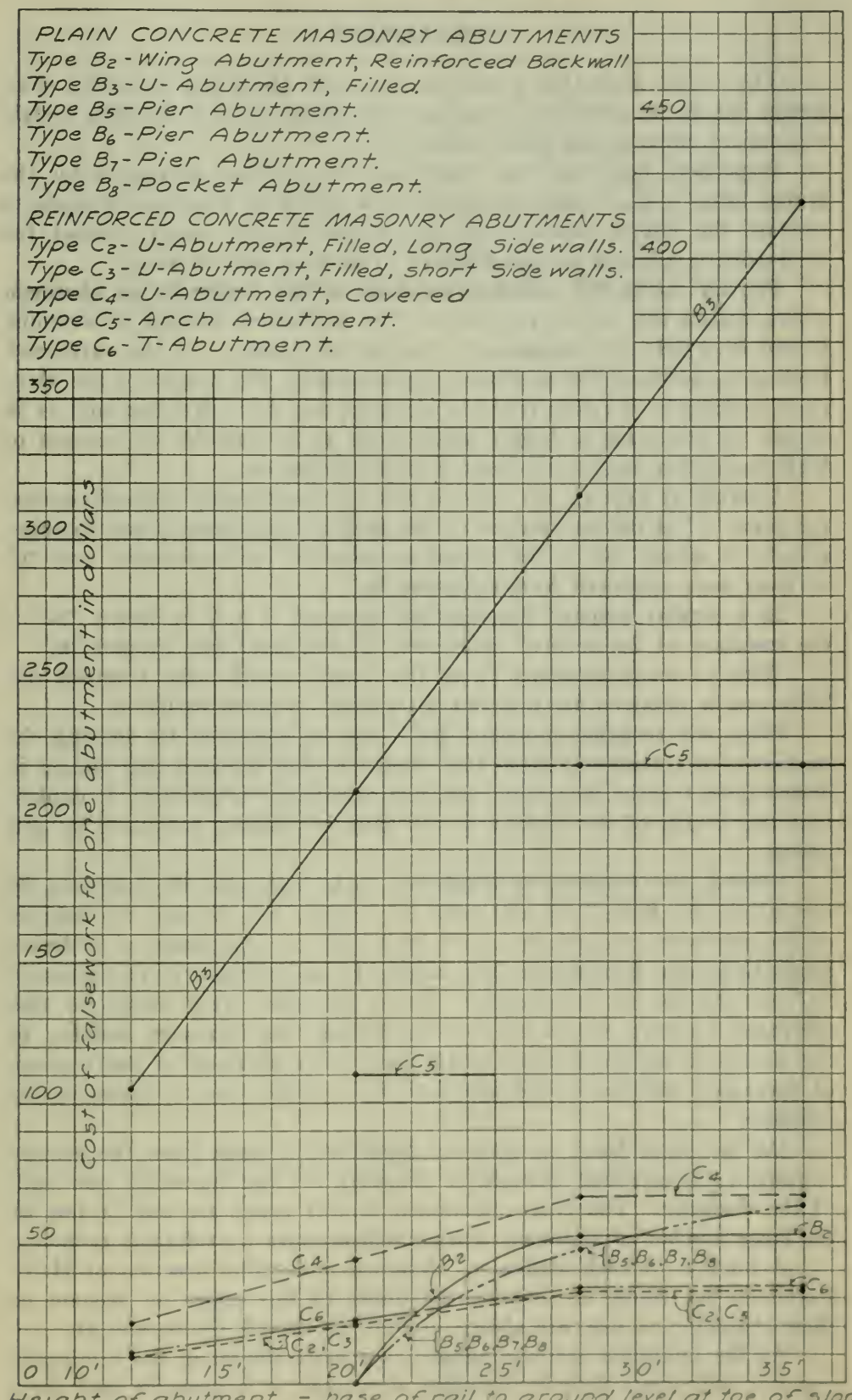


Diagram Showing Cost of Falsework for Abutments of Various Heights

Fig. 64

CONCLUSION.

The writer finds that a general statement about the foregoing abutments has to be qualified in so many directions that it becomes merely a group of more or less disconnected facts.

Inspection, however, will show that the cheapest abutments for the higher fills, C_3, C_6, C_7 and B_8, are those in which no provision is made to restrain the lateral pressure of the earthwork, but where instead the earthwork is allowed to spill forward to its own natural slope.

Fig. 43 shows the principal elements in the design of an abutment which resists the lateral pressure of the earthwork instead of avoiding it and in which the resistance to the lateral pressure of the earthwork tending to overturn the abutment is provided by the weight of the abutment neatwork. In this type the designer has little freedom and is in danger of producing a design which tends to be unstable on account of high foundation pressure at the toe of the abutment.

Looking at Fig. 43, we can see that the overturning moment around the point "k" at the intersection of the face of the neatwork and footings, is $p_3.l_3$, in which "p_3" is the lateral pressure of the earthwork, and "l_3" its lever arm, measured from the point "k."

In a similar manner the resisting moment is $p_2.l_2$ in which "p_2" is the resultant of the vertical loads and "l_2" the lever arm around "k."

With so many elements fixed, the ways in which the required stability can be obtained are few and not subject to much variation.

First, the resisting moment "$p_2.l_2$" can be increased by altering the outline of the abutment from that shown in full lines to that shown in dotted lines, thereby increasing the lever arm from "l_2" to "l_e." It is plain that the length of the lever arm can only be slightly increased by this means.

Second, the moment of resistance "$p_2.l_2$" can also be increased by increasing the force "p_2" and thus, of course, the moment of stability of the neatwork around the point "k." But in abutments of ordinary proportions any increase in "p_2" results in an increase in the pressure "p_7" on the toe of the footing. If no provision were made for this increased pressure on the toe of the footing, the increased stability of the neatwork on the footing would have been obtained at the expense of decreased stability of the abutment as a whole, due to excessive toe pressure.

On the other hand, as soon as departure is made from the gravity abutment, the greatest latitude is obtained for the ingenuity and skill of the designer. The types mentioned in this paper are only a few of the large number of abutment types which promise considerable economy.

A number of such abutments, designed under the direction of H. C. Lothholz, but which are outside the limits of this paper on account of their character or size, are shown in Figs. 65, 66, 68, 69, 70 and 71.

As the minimum sections adopted are more liberal in the reinforced concrete abutments than in the plain abutments, it is probable that there

is a wider margin for new economies in the reinforced than there is in the plain abutments. In the reinforced abutments a minimum section of 1 ft. 3 in. was used in a few places, but at the greater number of points the minimum thickness of concrete adopted was 1 ft. 9 in. to 2 ft. without regard to the load which it was to carry. If we compare the above thickness of reinforced concrete section with the thicknesses shown in Fig. 72, which is a drawing from a foreign textbook,* it would seem that the possible economies have not been exhausted.

*Der Eisenbeton in Theorie und Konstruktion, Rudolph Saliger, Leipzig, 1911. Alfred Kroner Verlag.

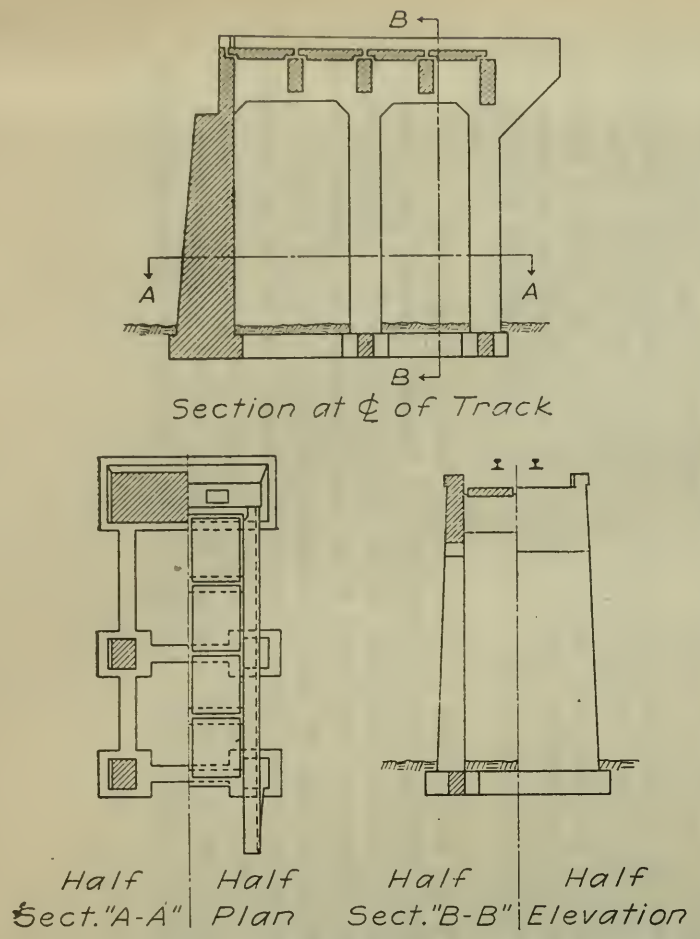


Fig. 65

LINE DIAGRAM EAST ABUTMENT SILVER CREEK VIADUCT.

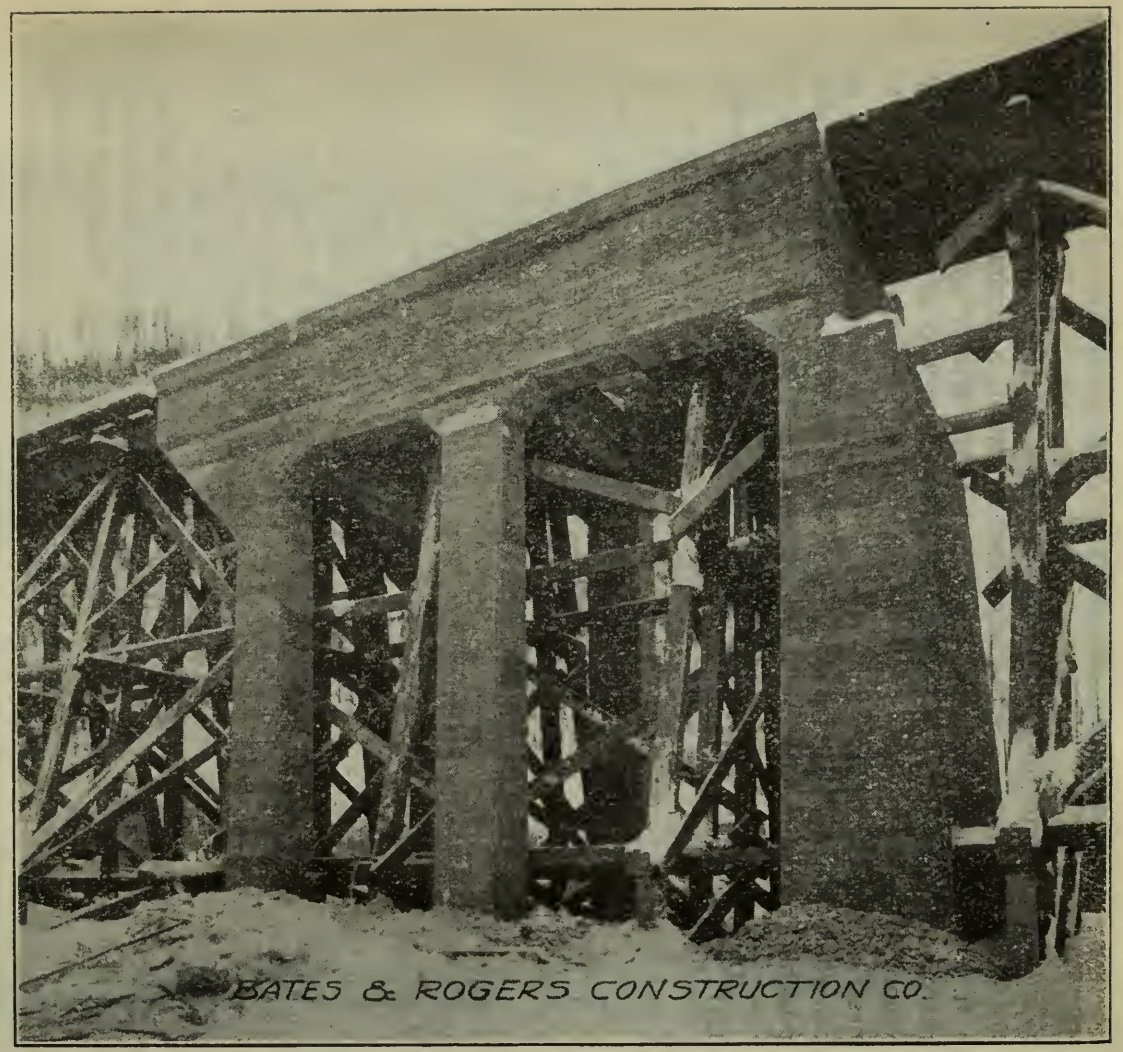


FIG. 66—EAST ABUTMENT SILVER CREEK VIADUCT, C. M. & P. S. RY.

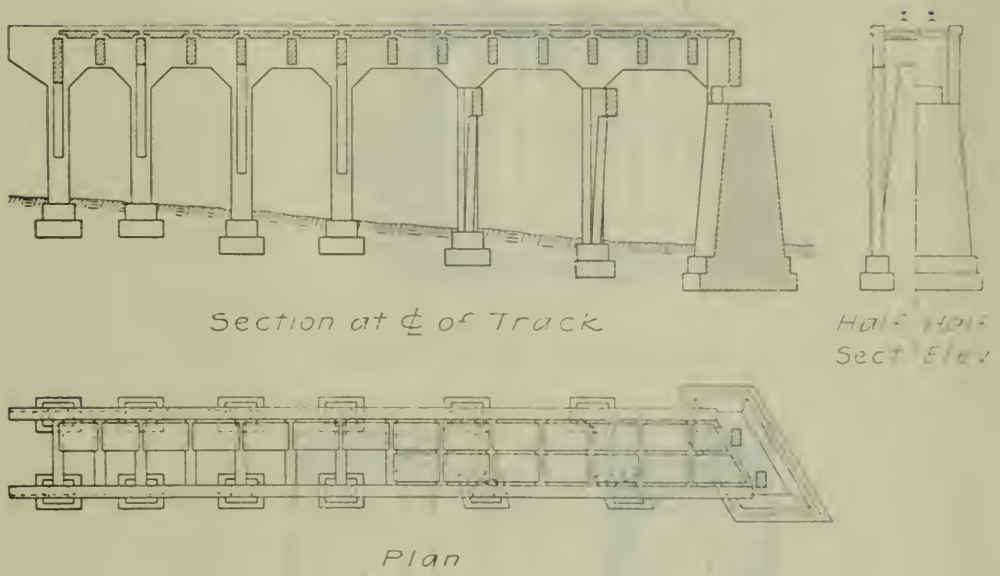


Fig. 68

LINE DIAGRAM ABUTMENT SPOKANE RIVER BRIDGE.

FIG. 69—ABUTMENT SPOKANE RIVER BRIDGE. ABUTMENT CONTAINS OPENINGS FOR UNDER CROSSINGS.

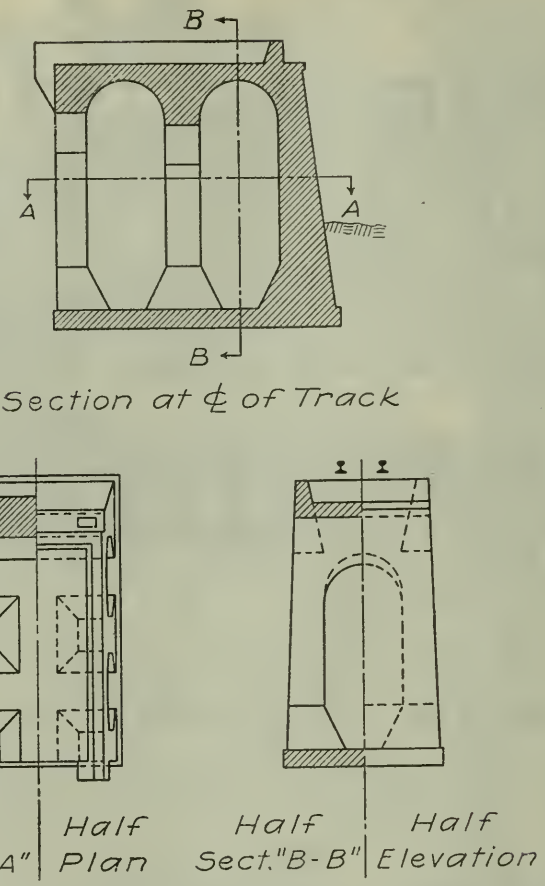


FIG. 70—LINE DIAGRAM ABUTMENT SIXTEEN MILE BRIDGE.

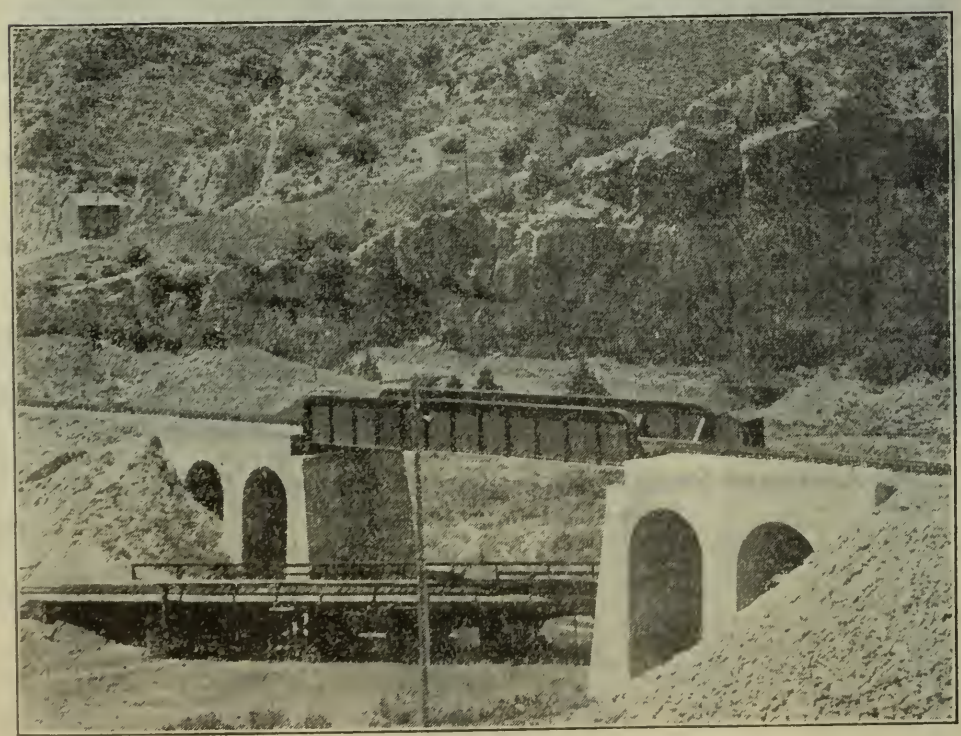


FIG. 71—ABUTMENTS SIXTEEN MILE CREEK BRIDGE ON C. M. & P. S. RY. NEAR LOMBARD, MONT.

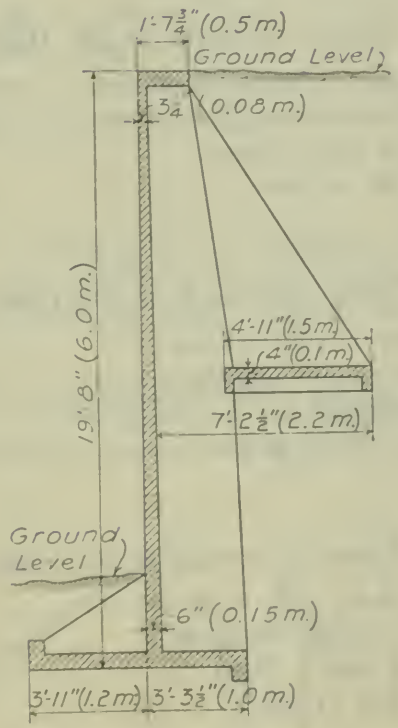

1'-7¾" (0.5 m.)
Ground Level
¾ (0.08 m.)
19'-8" (6.0 m.)
4'-11" (1.5 m.)
4" (0.1 m.)
7'-2½" (2.2 m.)
Ground Level
6" (0.15 m.)
3'-11" (1.2 m.)
3'-3½" (1.0 m.)

Fig 72

WRITTEN DISCUSSION ON "DESIGN OF RAILWAY BRIDGE ABUTMENTS."

Mr. J. L. Campbell (El Paso & Southwestern) :—Referring to "The Design of Railway Bridge Abutments," by J. H. Prior, Assistant Engineer, Chicago, Milwaukee & St. Paul Railway, in the November, 1911, Bulletin, I enclose herewith Fig. 73, showing a type of buried abutment which we have found more economical than wing abutments for high embankments. Referring to this figure, the buried abutment involves the use of a concrete pier and a deck plate girder, both of which are included in the comparative estimates that follow. The pier is assumed to replace a wing abutment in position.

Buried Abutment 22 Ft. High.

Excavation, 44 cu. yds. at $1.00	$44.00
Concrete, 177 cu. yds. at $7.00	1,239.00
Riprap, 150 cu. yds. at $1.50	225.00
Steel, 18,000 lbs. at 3¾c	675.00
	$2,183.00

Wing Abutment 22 Ft. High.

Excavation, 90 cu. yds. at $1.00	$90.00
Concrete, 290 cu. yds. at $7.00	2,030.00
Excess embankment, 445 cu. yds. at 20c	89.00
Riprap, 50 cu. yds. at $1.50	75.00
	$2,284.00

Buried Abutment 30 Ft. High.

Excavation, 50 cu. yds. at $1.00	$50.00
Concrete, 238 cu. yds. at $7.00	1,666.00
Riprap, 240 cu. yds. at $1.50	360.00
Steel, 37,000 lbs. at 3¾c	1,388.00
	$3,464.00

Wing Abutment 30 Ft. High.

Excavation, 140 cu. yds. at $1.00	$140.00
Concrete, 540 cu. yds. at $7.00	3,780.00
Excess embankment, 1,350 cu. yds. at 20c	270.00
Riprap, 80 cu. yds. at $1.50	120.00
	$4,310.00

The comparative estimates assume the ground to be level. Ordinarily the foundation of the abutment is higher than that of the pier, in which case the cost of the abutment is reduced. In some cases no riprap is required.

Referring again to Fig. 73: The embankment is assumed to be 30 ft. high. The pier and the embankment span, 40 ft. long, are a more economical arrangement than the elimination of the pier and extension of the adjacent span to the buried abutment. For example, assume the adjacent span to be a 60-ft. deck plate girder, and that it extends to the abutment, making a girder span 100 ft. long. The comparative estimate is then as follows:

For Single Span.

1 100 ft. girder, 160,000 lbs. at 3¾c.....	$6,000.00

For Pier and Embankment Span.

Excavation, 30 cu. yds. at $1.00.....	$30.00
Concrete, 140 cu. yds. at $7.00.....	840.00
1 40 ft. girder, 37,000 lbs. at 3¾c.....	1,387.50
1 60 ft. girder, 67,000 lbs. at 3¾c.....	2,512.50
	$4,770.00

The difference in favor of the arrangement shown in Fig. 73 will increase rapidly as the height of the embankment increases. Modern railway construction involves many bridges connecting embankments

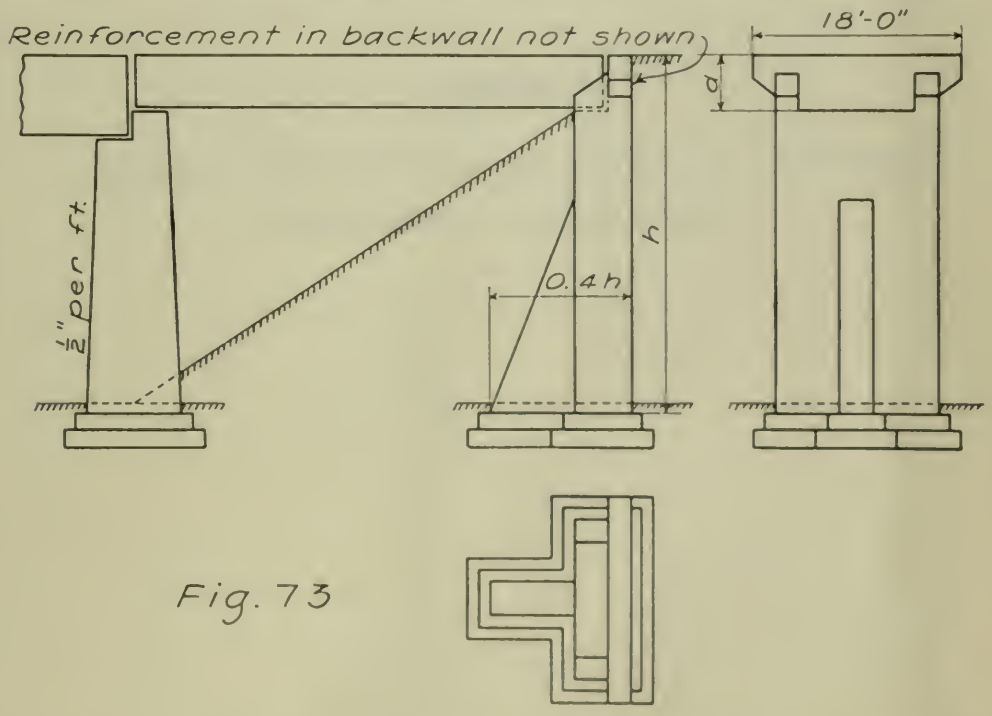


Fig. 73

too high for wing abutments. The buried abutment is an economical substitute when designed with due regard to the character of its foundation and of the embankment surrounding it. For embankments in which the material is stable even when wet, the type of buried abutment

shown will generally be found to have the necessary stability. However, numerous high embankments in many parts of the country do not become stable for several years after being built, in which case it is often difficult to determine the proportions and minimum dimensions required in a high abutment buried in such an embankment. When high embankments start to run off the right-of-way, as they sometimes do, it is not always the case that that portion of the embankment in front of the buried abutment gives very much support to the latter.

Mr. J. H. Prior:—Mr. Campbell's estimates on his buried abutment as a substitute for a wing abutment would seem to bear out the findings of this paper; that an abutment of this general character is more economical for moderate and high fills than a wing abutment.

The buried abutment and wing abutment which he mentions correspond in a general way, as far as design is concerned, to our abutments B-6 and B-2, and if his estimated costs are platted on figures 44 and 45, it will be seen that the total costs bear a similar relation.

We agree with his figures which show that it is cheaper to obtain the increased length of bridge required by the buried abutment by means of an additional approach span than it is to obtain this increased length by increasing the length of the end span.

Appendix A.

SUMMARY OF THE VARIOUS TYPES OF ABUTMENTS DESCRIBED IN THIS PAPER

I. Stone Masonry Abutments:

- Type A_1, Wing Abutments;
- Type A_2, U Abutments;
- Type A_3, T Abutments;

II. Plain Concrete Masonry Abutments:

- Type B_1, Wing Abutments, plain concrete back wall;
- Type B_2, Wing Abutments, reinforced concrete back wall;
- Type B_3, U Abutments, filled;
- Type B_4, T Abutments;
- Type B_5, Pier Abutment, transverse beam on concrete columns;
- Type B_6, Pier Abutment, plain concrete buttress;
- Type B_7, Pier Abutment, reinforced concrete buttress
- Type B_8, Pocket Abutment;

III. Reinforced Concrete Masonry Abutments:

- Type C_1, Counterfort Wing Abutments;
- Type C_2, U Abutments, filled, long side walls;
- Type C_3, U Abutments, filled, short side walls;
- Type C_4, U Abutments, covered;
- Type C_5, Arch Abutments;
- Type C_6, T Abutments;
- Type C_7, Trestle Abutments.

EQUATED TONNAGE RATING FOR LOCOMOTIVES.

(Bulletin 138.)

By M. H. Wickhorst.

The method of locomotive tonnage rating and the train resistance tables described in this paper were first worked up by the Laboratory of the Chicago, Burlington & Quincy Railroad about the year 1902, and were presented by the author in a paper before the Western Railway Club, March 17, 1903. The paper was later revised and the tables considerably extended, under the direction of the author, under date of September 3, 1908, and it is these that now constitute the present paper. Credit for such merit as this work may possess is due to a number of persons, and the work of revision in particular was done mostly by Mr. W. A. Pownall, of the Chicago, Burlington & Quincy Railroad Laboratory at Aurora, Ill. Permission to publish this material was kindly given by Mr. H. E. Byram, Vice-President, Chicago, Burlington & Quincy Railroad. This revision was used as a code of instructions for those doing tonnage rating work on the road mentioned.

TONNAGE RATING OF LOCOMOTIVES.

CHICAGO, BURLINGTON & QUINCY RAILROAD COMPANY.

In establishing a tonnage rate for an engine we aim to load the engine up to near its maximum pulling capacity and yet not load it so heavily that it will stall on any of the hills, or be on the road an excessive length of time.

The work of engine rating consists of: (1) Determining the maximum working tractive force the engine can maintain under average conditions over the ruling grade; and (2) to balance this with an equal amount of total train resistance on the ruling grade. We have tractive force formulæ and curves of train resistance from actual tests which are worked up into tables convenient for use in this work. These are given later on in this article.

The tonnage rater, in rating a division, must first get an alinement and grade profile of the division and make a careful study of the grades, curves, etc., for the purpose of determining the ruling grade and estimating about what percentage of the maximum tractive force an engine can consistently maintain and get over the road with in good time and without stalling. There is also the question of momentum grade as affecting the ruling grade. This will be explained later.

He should also, if consistent with operating conditions, divide the main runs of the division into rating divisions whenever there is a sufficient change in ruling grade to warrant two different rates. For instance, one run on the Galesburg Division of the Chicago, Burlington & Quincy Railroad is from Quincy to Galesburg; from Quincy to Bushnell is 70 miles, with a ruling grade of 0.7 per cent.; from Bushnell to Galesburg is 30 miles, with a ruling grade of 0.3 per cent. As Bushnell is a point where there is a great deal of freight to fill up with, there should be two rates for the Quincy-to-Galesburg run. If there were no important points where freight originated between Quincy and Galesburg, we would probably make a straight through rate from Quincy to Galesburg.

Having settled on these, the rater will consult the equated tonnage tables for the grade in question, and using the predetermined tractive force as the train resistance, he will get a trial rate.

The next step is to ride engines hauling this trial rate and see how the estimate works out in practice. There are many local influencing conditions which cannot be seen on the profile chart, such as differences in roadbed, speed limits, some grades being protected from winds by trees or cuts, overworking of firemen, etc. Very often sidings or the

approach to them will be on a heavy grade, so that if an engine had to stop to head in at one of them, it would be unable to start the train again. The approach to crossovers, home semaphores, or any place where trains have to be stopped under ordinary operating conditions, are similar instances that have to be considered in making the rate. If, however, to consider such a point would lower the rate very materially and if the point in question were one where wise despatching would eliminate most of the stops at the place, it should be ignored in making the rate. These will show up on the trial trips, and the rater can, in a few trips, check up his rates and readjust, if necessary, for the final rating.

If a train averages less than ten miles an hour between terminals (except on runs of less than 100 miles), the engine and train crew are on the road an excessive length of time. In practice we find that ordinarily if an engine be loaded so that her average speed *in motion* is twenty miles an hour, the average speed between terminals will not fall under ten miles per hour.

Outside the ability of the engine to handle her train, density of traffic and efficiency of despatching are factors to be considered. The question of speed is an important one, and the engine rater should keep accurate record of stops and time on road on his trial trips, and rate accordingly.

The length of the division is another influencing factor. On a short division, of say, 60 miles in length, it is economy, traffic permitting, to load the engines a little more heavily; whereas, on a 160-mile division the rate should be lowered on account of excessive time on the road, the possibility of heavy or clinkered fires, etc.

Following is the method of arriving at the equated tonnage rates:

TRACTIVE FORCE.

(1) *Tractive Force at Tender Drawbar.*

For figuring the maximum tractive force that an engine may develop at the tender drawbar on level track for simple engines, we use the following formula:

$$TF = \frac{.85\,P\,d^2 s}{D}$$

Where P = maximum boiler pressure in lbs. per sq. in.
d = diameter of cylinder in inches
s = stroke in inches
D = diameter of drivers in inches
TF = tractive force in pounds.

This formula assumes that the mean effective pressure in the cylinders at full stroke is 92 per cent. of the maximum boiler pressure, and that 92 per cent. of the work done by the cylinders is transmitted back to the drawbar behind the tender.

For compound engines we use the following formula, working compound:

Two cylinder compounds, $TF = \frac{.85\ P\ d_l^2 s}{D\ (r+1)}$

Four cylinder compounds, $TF = \frac{1.7\ P\ d_l^2 s}{D\ (r+1)}$

Two cylinder compounds working simple, $TF = \frac{.85\ P d_h^2 s}{D}$

Where d_l = diameter of low pressure cylinder in inches
r = ratio of cylinder volumes $(LP \div HP)$
d_h = diameter of high pressure cylinder.

(2) *Tractive Force on Grade.*

On a grade the tractive force of an engine is less, due to the fact that she must lift her own weight up the hill, which absorbs some of the work performed by the cylinders and leaves less to develop at the drawbar.

The amount to be deducted for this engine grade resistance is found by the following formula:

Engine Grade Resistance $= 20\ W\ G$;
Where $W =$ weight of engine and tender in tons
$G =$ grade in per cent.

(3) *Net Working Tractive Force.*

Having obtained the maximum effective tractive force at tender drawbar, a certain allowance must be made for small drops in steam pressure as affecting the tractive force, and for an occasional stuck brake, excess of billed over actual tonnage, etc., as affecting train resistance. A variable and sometimes very considerable allowance has to be made depending on the profile of the road; i. e., where the run as a whole is hard and the grades long, we take from 80 per cent. of the tractive force down to as low as 65 per cent. on the lower grade divisions. An example of this would be a division of perhaps 120 miles with a large amount of 0.3 per cent. grade; this would probably be rated as a 0.3 per cent. grade using 65 or 70 per cent. of the tractive force as the total train resistance over this grade. If sufficient allowance were not made we would find that while the engine would probably take the train over without stalling, the time would be very slow, the fire would get in bad shape, and on the low-grade divisions with our heavy power the fireman would be unable to stand the work.

To find, therefore, the net working tractive force, we take a certain predetermined percentage of the drawbar tractive force (afterwards checked by road test), and subtract from this the engine grade resistance. The resulting net tractive force is the same as the total train resistance over the ruling grade, and is the figure that determines the rate.

For convenience in working rate schedules and calculating, tables are given, showing tractive forces, weights and amount of heating surface for the different classes of engines of the Chicago, Burlington & Quincy Railroad. (See Fig. 1.)

TRAIN RESISTANCE.

Train resistance consists of three primary resistances, as follows:

(1) Acceleration resistance.

(2) Grade resistance.

(3) Friction.

Acceleration and grade resistances are elementary resistances, dependent only upon the amount of tonnage, and not upon the form of the tonnage, such as in empty or loaded cars, etc. Friction is a compound resistance dependent upon a good many conditions, such as kind of cars, load in cars, condition of track, condition of trucks, wind, temperature of air, curves, etc. The composition of train resistance is shown below:

- Train Resistance
  - Acceleration Resistance, depends on tonnage only.
  - Grade Resistance, depends on tonnage only. — 20 lbs. per ton for 1 per cent. grade, or about .4 lb. for each foot per mile of grade.
  - Friction
    - Journal. Depends on design and lubrication.
    - Rolling. Depends on solidity of roadbed.
    - Flange.
    - Curve
      - Sliding of one tread, in each pair, on the rail.
      - Flange Friction.
    - Side bearings and center plates cause flange friction.
    - Wind
      - Wind against body of car.
      - Flange Friction.

    — Varies from 2½ to 12 lbs. per ton.

Note—Flange friction consists of that due to curves, side bearings and center plates, winds, etc.

(1) *Acceleration Resistance.*

In rating slow freight trains acceleration resistance need very seldom be considered, except on momentum grades. Here it comes as negative resistance, and will be considered later under the head of momentum grades.

(2) *Grade Resistance.*

This, generally, is the largest component of the freight train resistance, and is dependent only on the tonnage on any given grade. The grade resistance per ton may be figured by the following formula:

Where $r_g = 20\,G$

r_g = grade resistance in lbs. per ton

G = grade in per cent.

(3) *Friction.*

As stated above, the frictional resistance varies considerably. The friction expressed in pounds per ton drawbar pull increases as the speed increases, decreases as the gross weight of a car and its freight increases, and increases, in a general way, as the temperature of the air decreases. It varies for freight cars at freight speeds between limits of about 2 lbs. per ton and 12 or more lbs. per ton. Fig. 2 shows some curves of friction resistance of freight cars at speeds of 20 miles per hour. These curves show the relation between the gross weight per car in tons plotted horizontally, and the resistance per ton in pounds plotted vertically for four different weather conditions, as follows:

(1) Temperature above 30 degrees Fahrenheit, and not much wind.

(2) Temperature between zero and 30 degrees Fahrenheit, *or* strong head or side wind, *or* frosty rail.

(3) Temperature between zero and 30 degrees Fahrenheit *and* strong head or side wind, *or* temperature below zero and not much wind.

(4) Temperature below zero with strong head or side wind.

The curve showing resistance of freight cars in summer weather (above 30 degrees Fahrenheit) is the result of dynamometer tests by the Pennsylvania Railroad, and various results obtained by us fall in well with this curve.

The curve showing friction of freight cars for the third weather condition is one obtained by the Burlington from dynamometer tests during the winter of 1900-1901. This curve was formerly used for the resistance of cars in 10 degrees Fahrenheit to 30 degrees Fahrenheit weather, but we found that there was too wide a gap between the winter rates derived from this curve and the summer rate; i. e., for calm winter days an engine could easily take considerably more than the old winter weather rate, especially on the low-grade division. Accordingly, between these two curves was placed another curve for calm winter weather, *or* windy summer weather, and road tests indicated that rates derived from this curve were about right.

The curve for very severe winter weather was obtained by arbitrarily adding 2 lbs. per ton to the No. 3 curve. This seems to give the right result for grades 0.6 per cent. or over; for grades of 0.5 per cent. or lower, we deduct 10 per cent. from our No. 3 or "C" rate to get the "D" rate. This diagram also gives a curve of grade resistance based on the above formula.

Knowing the grade, the gross weight of a car, and the general weather condition, the total resistance per ton is found by adding together the grade and friction resistances per ton as found from these curves.

MOMENTUM GRADES.

Where the grade is not too long, the momentum, or the work stored in the train as motion, can often be used to help get the train over the grade. A body in motion has an amount of work stored in it dependent

upon its speed, and this stored work can be used to overcome the force of gravity, or in other words, take a train a certain distance up a hill. The amount of work so stored increases as the square of the speed. A body moving 30 miles per hour has sufficient work stored in it to carry it vertically upward about 30 ft.; one moving 60 miles per hour sufficient for 120 ft., etc. Therefore, a train approaching a hill at 30 miles per hour could be taken a vertical distance of 30 ft., due to the momentum, provided the friction were otherwise taken care of. On a grade 30 ft. to the mile this distance along the track would be one mile; on a 60-ft. grade, one-half mile, etc. Where this momentum is to be expended, or to run out, in a given distance, the propelling force can be expressed as a pull of so many pounds per ton, or as a certain total drawbar pull at the head end of the train, or as so much negative grade, thus cutting down the actual grade and producing a lower virtual grade. For our purpose the simplest method is to express momentum as so much negative grade and its value may be figured by the following formula:

$$G_m = 3.5 \frac{V^2}{x}$$

Where G_m = equivalent grade in per cent.
V = speed in miles per hour
x = distance traversed during retardation, in feet.

Where a minimum speed of five miles per hour at top of grade is assumed, the equivalent grade would be determined as follows:

$$G_m = 3.5 \frac{V^2 - 25}{x}$$

For convenience we show Fig. 3, from which can readily be obtained the equivalent grade in per cent., having the speed of approach and length of grade, based on this formula. Having the actual grade and the momentum expressed as equivalent grade, the virtual grade is equal to the actual grade minus the momentum grade. The actual resistance of the train is, then, that due to the virtual grade plus the friction.

TRACTIVE FORCE AT SPEED.

Where the speed is above 8 or 10 miles per hour, the maximum tractive force cannot be sustained on account of the inability of the boiler to furnish sufficient steam, and when calculating tonnage rates on momentum grades, it is necessary to determine the average tractive force from the bottom to the top of the hill. It might be well to mention here that some engines are a bit over-cylindered; i. e., their tractive force figured from the cylinders is higher than the boiler can maintain, even at lower speeds. On the low-grade lines, where the train has to run at a considerable speed over the ruling grade, such engines should really be rated on their boiler capacities. This falling off of tractive force due to limit of boiler is shown for our various engines at speeds up to 40 miles per hour in Fig. 4.

The tractive force shown on these curves as limited by the boiler is obtained by the following formula:

$$\text{Tractive Force} = \frac{375 \times .43\,H}{S} - R$$

Where H = heating surface in sq. ft.
S = speed in miles per hour
R = the total resistance in pounds of the engine and tender.

The expression .43 H gives the maximum cylinder horsepower of the locomotive assuming an evaporation of 12 lbs. of water per square foot of heating surface per hour, and a cylinder water rate of 28 lbs. of water per horsepower hour. This is a formula given by Professor Goss and the results of our locomotive tests agree well with it, so we have adopted the same. The expression $\frac{375 \times .43\,H}{S}$ converts horsepower into cylinder tractive force. Now to convert this cylinder tractive force into drawbar tractive force we must subtract R, the total resistance of the engine and tender. R is gotten by multiplying the weight in tons of the engine and tender with half load of coal and water by the resistance per ton at given speed as obtained from curve in Fig. 5. This curve is the average of the engine resistance curves of engines C., B. & Q. 1967, 1989, 3156, C. & A. 340, and Erie 1776, all of which engines were pulling full tonnage on the tests from which these curves were taken.

The tractive force shown on the above-mentioned sheets of curves, at the average speed, will generally be found satisfactory. In figuring on a momentum grade it is necessary to know the speed limit of the division for freight trains, and whether there are any permanent slow orders at foot of hills due to bad curves, crossover, etc. It is hardly safe to regard as a momentum grade any grade over 1½ miles long or one that has several reverse curves on it.

EQUATED TONNAGE TABLES.

Having the total resistance per ton of any given train and the maximum working tractive force of the engine, the thing is now to get sufficient tonnage to just make total train resistance to balance this tractive force. The number of tons that will give this total resistance will, of course, vary with the load per car and the weather conditions, increasing as the load per car increases, and decreasing as the weather conditions become more severe. For operating use we get up a rate table, showing the number of tons for various number of cars in the train and for four weather conditions, namely:

Rate "A"—Temperature above 30 degrees Fahrenheit and not much wind.

Rate "B"—Temperature between zero and 30 degrees Fahrenheit, *or* strong head or side wind, *or* frosty rail.

Rate "C"—Temperature between zero and 30 degrees Fahrenheit,

and strong head or side wind, *or* temperature below zero and not much wind.

Rate "D"—Temperature below zero, with strong head or side wind.

The method in detail of obtaining these tables is shown in Fig. 6.

EXPLANATION OF METHOD.

The tables in Fig. 6 show method used in calculating equated tonnage tables. The various tonnages shown all have the same drawbar resistance of 20,000 lbs., and are calculated for a 0.5 per cent. grade at freight speeds of 20 miles per hour. The method is to make a column of gross car weights from 10 tons to 60 tons, column 1. In column 2 is shown the resistance per ton of cars of the various gross weights. This includes the grade and the friction resistances per ton. Next we divide 20,000 by the resistance per ton, and get column 3, showing the various tonnages having the total train resistance of 20,000 lbs. Then by dividing the number of tons by the gross weight per car we get column 4, showing the number of cars in the train corresponding to the various tonnages. The columns of tons are then interpolated to the nearest even figure divisible by 5 and corresponding to an even number of cars divisible by 5 and placed in column 12, which is the column as finally used in rate schedules. Having column 12, the columns 5 to 10, inclusive, are obtained from columns 11 and 12 by multiplying by a suitable factor. For example, columns 5 and 6 are the intermediate steps in getting the "B" rate, and are gotten by use of the factor .83, the ratio of resistance per ton of a 40-ton car on a 0.5 per cent. grade in warm weather (curve 1), to the resistance per ton of a 40-ton car on a 0.5 per cent. grade in zero to 30 degrees Fahrenheit weather (curve 2). This ratio or factor would vary slightly between the 10-ton car and the 60-ton car; the factors shown are gotten by taking an average of the ratios for the cars of following weights: 10, 11, 12, 14, 16, 18, 20, 25, 30, 40, 50 and 60 tons. The tons and cars thus obtained are interpolated to even figures and the tonnage placed in column 13, opposite the proper number of cars. The other columns are obtained similarly by using the suitable factor selected from table shown on the print.

Tables have been made showing the tonnages for grades from 0.3 per cent. to 1.6 per cent., and for total train resistances from 10,000 to 35,000 lbs. When, therefore, we have decided on the maximum working tractive force on a given grade, we simply select from the set of tables the suitable schedule and give this as the tonnage rate schedule for the engine. For practical use the rates thus decided upon are gotten out on tonnage rating sheets for each division, which show the number of cars and tons for the different rating divisions and for all classes of engines on that division. A page from the time-card of the Aurora Division of the Chicago, Burlington & Quincy Railroad, showing engine rates on that division, is given with this article as Fig. 7.

C. B. & Q. R. R. Laboratory. Aurora, Ill. Lab No. 656-225-10 T 2

TRACTIVE FORCES, WEIGHTS AND HEATING SURFACES

NOTE:- WEIGHT INCLUDES TENDER WITH FULL LOAD COAL AND WATER.

CLASS	D_2	D_3	D_4	D_7	H_1	H_1	H_1	H_2	H_3	H_4	K_1	K_1	K_2
CYLINDERS	20"x24"	22"x28"	22"x28"	20"x26"	19"x24"	19"x24"	19"x24"	19"x24"	19"x26"	19"x26"	19"x24"	19"x24"	19"x24"
DRIVERS DIAM.	52"	52"	57"	56	64"	64"	69"	64"	64"	64"	58"	64"	64"
STEAM PRESS	160	180	210	180	160	170	170	180	200	200	160	160	180
TRACTIVE FORCE	25000	39500	42500	28400	18400	19600	18100	20700	24900	24900	20300	18400	20700
WEIGHT (LBS)	210,960	324,500	352,600	238,300	214,700	214,700	214,700	219,700	225,750	238,200	214,050	214,050	223,250
HEATING SURFACE.	1555	2983.9	3733.3	1940.3	1584	1584	1584	1685	1715.4	2047.8	1860.9	1860.9	1884
CLASS	K_2	K_3	K_3	K_4	K_4	K_5	K_6	K_9	L_1	P_1 Comp.	P_2	P_2 Comp.	P_3 Comp
CYLINDERS	19"x24"	19"x24"	19"x24"	19"x26"	19"x26"	19"x26"	16"x24"	18"x24"	22"x28"	13½"x23"x28"	20"x26"	15"x25"x26"	15"x25"x26"
DRIVERS DIAM.	58	64"	69"	72	64"	69"	56	56	50"	78"	78	78"	78"
STEAM PRESS	180	160	160	200	200	210	170	160	160	210	210	210	210
TRACTIVE FORCE	22800	18400	17100	22200	24900	24300	16100	18880	36900	17700	23800	21400	21400
WEIGHT (LBS)	223,250	208,200	208,200	251,300	251,300	303,900	172,970		242,950	279,450	307,400	304,060	317,000
HEATING SURFACE	1884	1717	1717	2430	2430	2879.4			2352	2358.6	2990	2990	3206
CLASS	P_3 Comp	P_4	R_1	R_2	R_3	R_4	R_5	S_1	T_1				
CYLINDERS	15"x25"x26"	19"x26"	15"x24"	20"x24"	21"x26"	22"x28"	22"x28"	22"x28"	21½"x33"x32"				
DRIVERS DIAM	74"	78"	64"	64"	69"	69"	69"	74"	55				
STEAM PRESS	210	200	190	200	200	210	210	210	200				
TRACTIVE FORCE	22500	20450	21860	25500	28200	35000	35000	31100	64100				
WEIGHT (LBS)	317,000	292,400	245,920	290,400	300,900	358,200	364,200	376,200					
HEATING SURFACE	3206	2504.9	1957.3	2884.1	3057.1	3503.4	3575.7	3932.7					

FIG. 1—TABLE OF TRACTIVE FORCE, WEIGHTS AND HEATING SURFACES OF C. B. & Q. R. R. ENGINES.

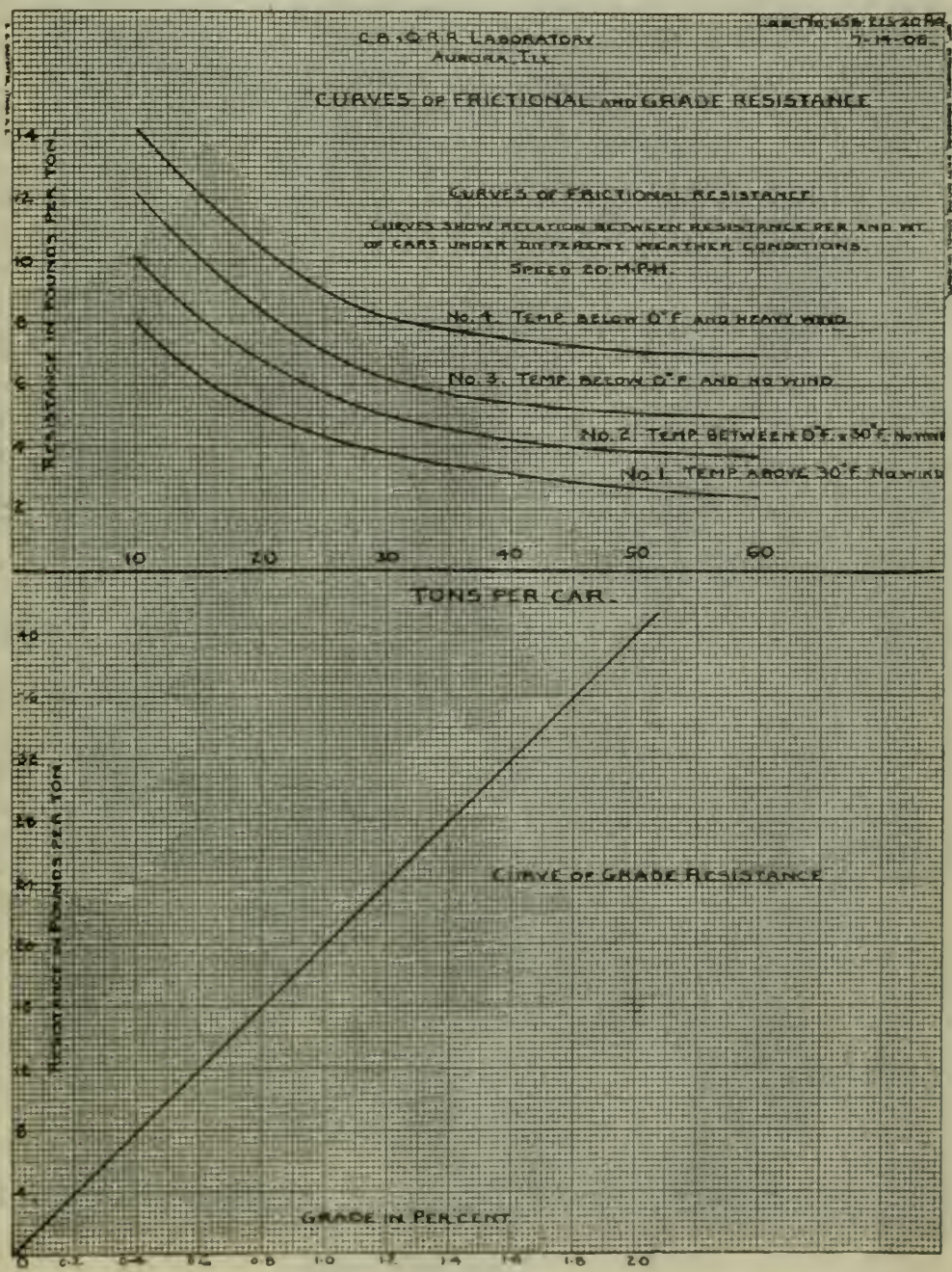

C.B. & Q. R.R. LABORATORY
AURORA, ILL.
CURVES OF FRICTIONAL AND GRADE RESISTANCE
CURVES OF FRICTIONAL RESISTANCE
CURVES SHOW RELATION BETWEEN RESISTANCE PER TON OF CARS UNDER DIFFERENT WEATHER CONDITIONS.
SPEED 20 M.P.H.
No. 4. TEMP. BELOW 0° F. AND HEAVY WIND.
No. 3. TEMP. BELOW 0° F. AND NO WIND.
No. 2. TEMP. BETWEEN 0° F. & 30° F.
No. 1. TEMP. ABOVE 30° F.
RESISTANCE IN POUNDS PER TON
TONS PER CAR.
CURVE OF GRADE RESISTANCE
RESISTANCE IN POUNDS PER TON
GRADE IN PER CENT.

FIG. 2—CURVES OF TRAIN RESISTANCE, FRICTIONAL AND GRADE.

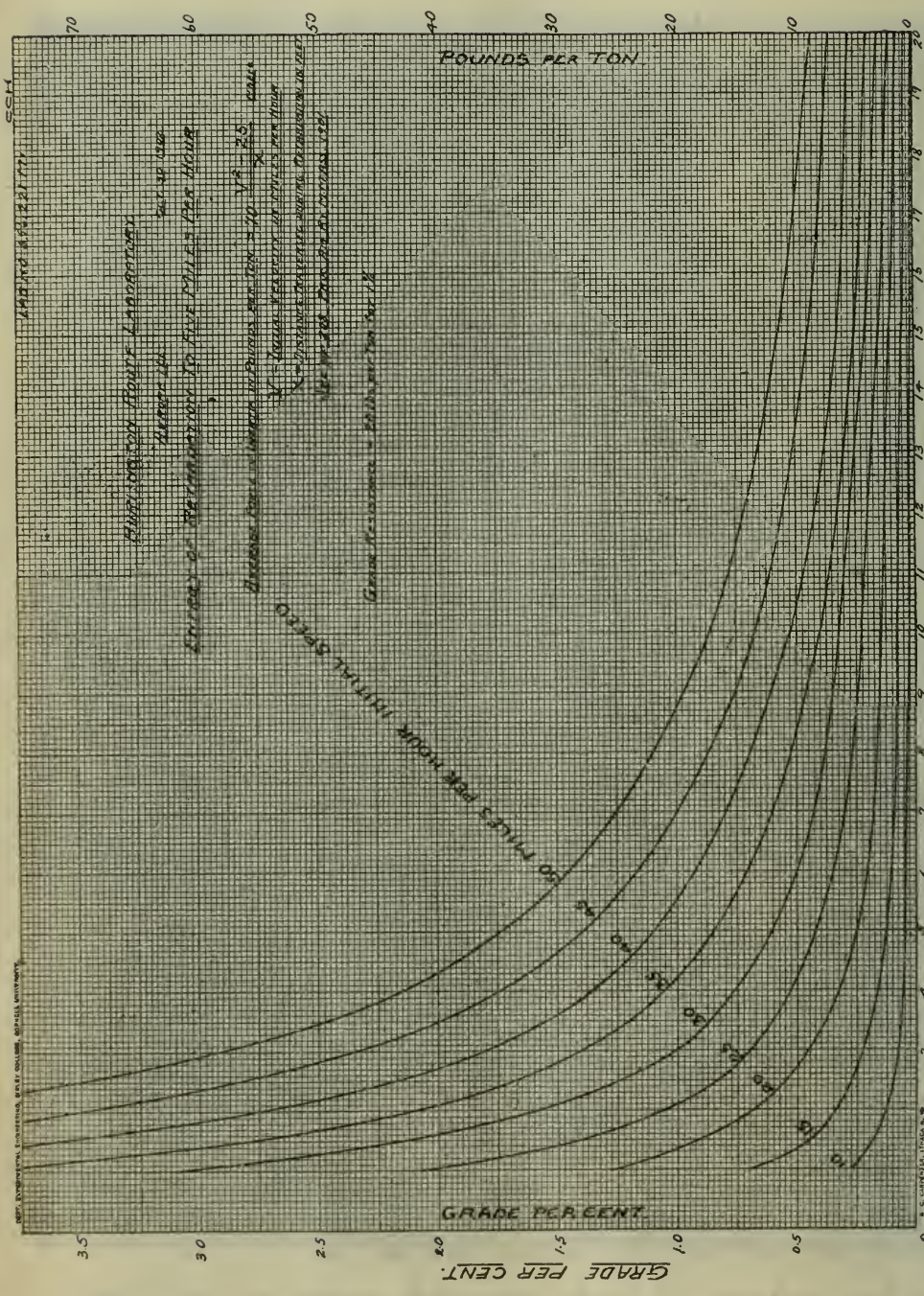


FIG. 3—CURVES OF NEGATIVE TRAIN RESISTANCE DUE TO MOMENTUM FIGURED IN PER CENT. OF GRADE.

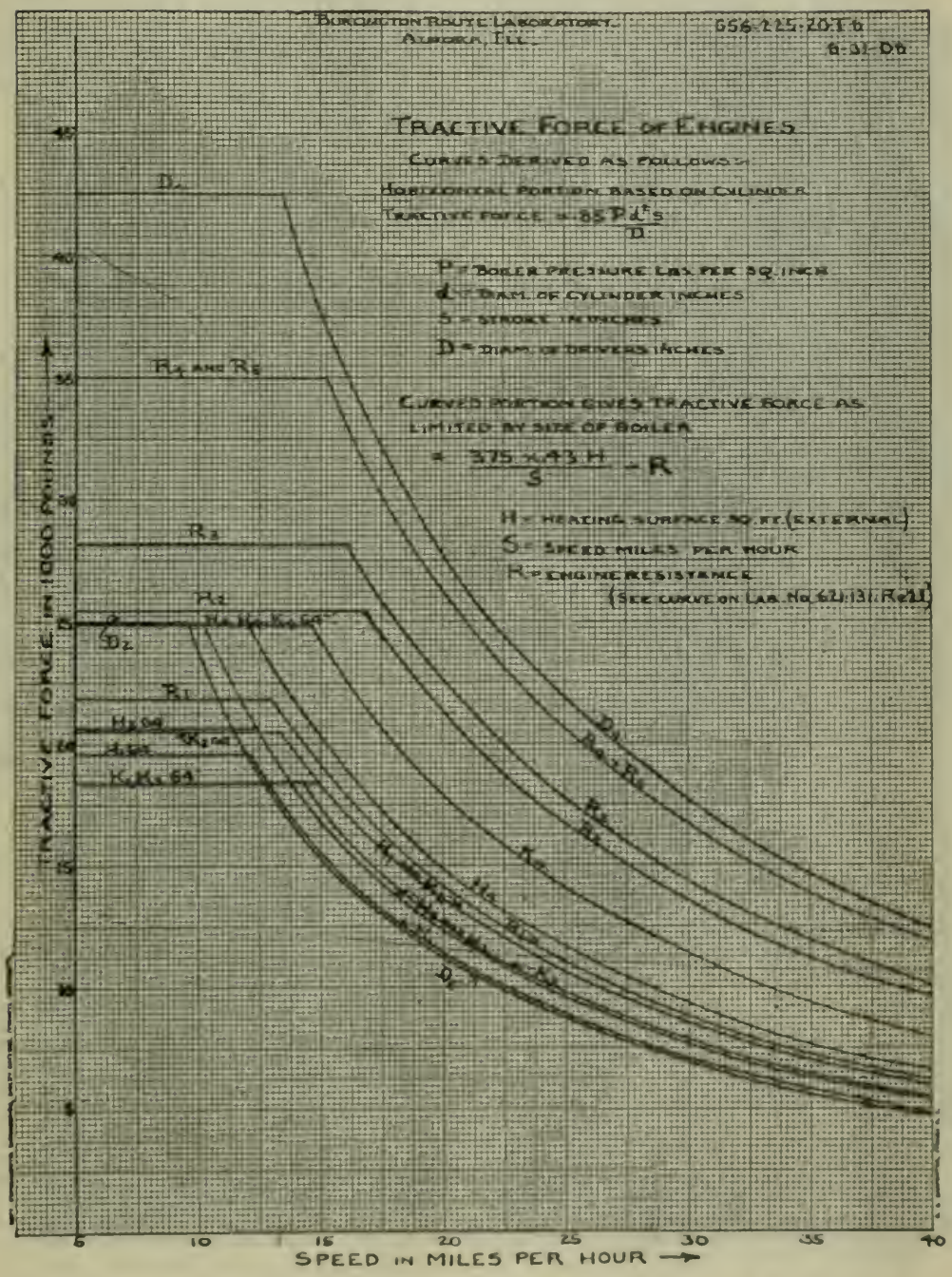

BURLINGTON ROUTE LABORATORY, AURORA, ILL.
656-225-20-T-6
6-31-Db
TRACTIVE FORCE OF ENGINES
CURVES DERIVED AS FOLLOWS:
HORIZONTAL PORTION BASED ON CYLINDER
TRACTIVE FORCE = .85 P d² S / D
P = BOILER PRESSURE LBS. PER SQ. INCH
d = DIAM. OF CYLINDER INCHES
S = STROKE IN INCHES
D = DIAM. OF DRIVERS INCHES
CURVED PORTION GIVES TRACTIVE FORCE AS LIMITED BY SIZE OF BOILER
= 375 × .43 H / S − R
H = HEATING SURFACE SQ. FT. (EXTERNAL)
S = SPEED MILES PER HOUR
R = ENGINE RESISTANCE
(SEE CURVE ON LAB. NO. 62-131-R-21)
TRACTIVE FORCE IN 1000 POUNDS
SPEED IN MILES PER HOUR →
5
10
15
20
25
30
35
40

FIG. 4—CURVES OF TRACTIVE FORCE OF ENGINES OF C. B. & Q. R. R.

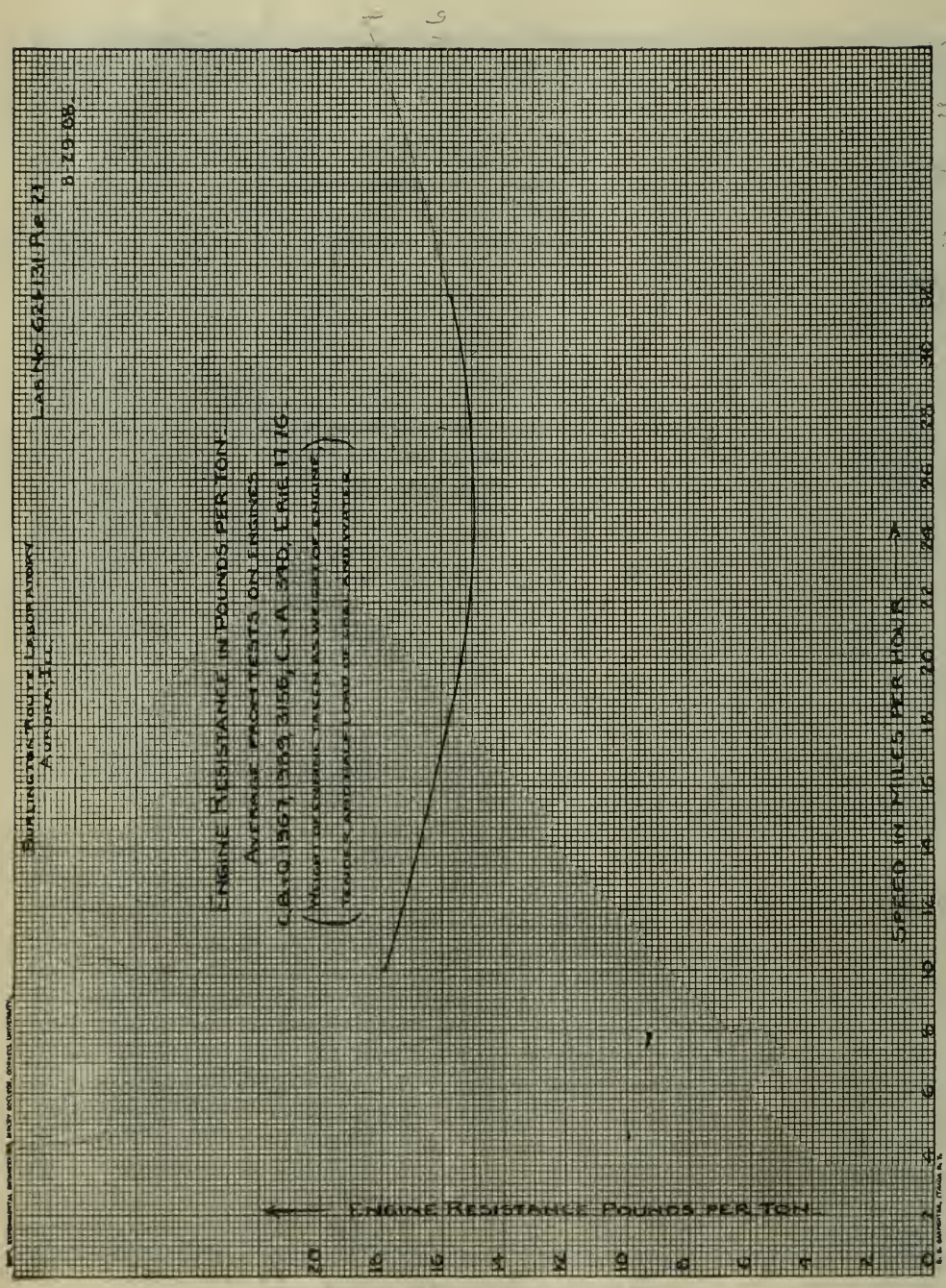

BURLINGTON-ROUTE LOCOMOTIVE
AURORA, ILL.
Lab. No. 624131 Rec'd 2-1
8-29-88
ENGINE RESISTANCE IN POUNDS PER TON
AVERAGE RESULTS ON ENGINES
C&I.Q. 1367, 1369, 3156, C.B.A. 248, ERIE 17-16
(WEIGHT OF ENGINES TAKEN AS WEIGHT OF ENGINE)
(TENDER CARRYING LOAD OF FUEL AND WATER)
ENGINE RESISTANCE POUNDS PER TON
SPEED IN MILES PER HOUR

FIG. 5—CURVE OF ENGINE RESISTANCE.

Sample Data Sheet and Method of Calculation.— EQUATED TONNAGE RATES. Grade 0.5%

Rate A: Temp. above 30° F. and not much wind. Rate B: Temp. between 0° F. and 30° F. or strong head or side wind, or frosty rail. Resistance 20,000 #

Rate C: Temp. between 0° and 30° F. and strong head or side wind, or temp. below 0° and calm. Rate D: Temp. below 0° with head or side wind.

Tons per car	Friction and grade resistance per ton	Rate A		Rate B		Rate C		Rate D		Cars	Rates.			
		Tons	Cars	Tons	Cars	Tons	Cars	Tons	Cars		A	B	C	D
10	17.9	1117	111.7	1042	90	930	91.5			100	1160			
11	17.5	1143	103.8	1060	85	960	83			95	1180			
12	17.1	1170	97.4	1080	81	980	78.6			90	1200	1040	935	
14	16.5	1212	86.6	1100	76	995	74.6			85	1220	1060	950	855
16	15.9	1257	78.6	1120	72	1010	70.6			80	1245	1080	970	870
18	15.5	1290	71.7	1143	67	1033	66.4			75	1270	1100	990	890
20	15.1	1324	66.2	1170	63	1053	62.2			70	1300	1125	1010	910
25	14.4	1389	55.6	1200	56	1080	58.1			65	1330	1150	1035	930
30	13.9	1439	48.0	1222	54	1105	53.5			60	1360	1180	1060	955
40	13.2	1514	37.9	1255	49	1130	49.8			55	1395	1210	1090	980
50	12.8	1565	31.3	1285	45	1160	45.6			50	1430	1250	1125	1010
60	12.5	1600	26.7	1320	40	1185	41.5			45	1465	1285	1160	1045
				1350	36	1215	37.4			40	1500	1320	1195	1075
				1380	31	1245	33.2			35	1535	1360	1230	1105
				1415	27	1275	29			30	1575	1400	1270	1140
				1455	22	1305	24.5			25	1615	1440	1310	1180
						1340	20.7			20		1490	1350	1215
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

T_A = Resistance per ton for Rate "A" conditions.

T_B = Resistance per ton for Rate "B" conditions.

T_C = Resistance per ton for Rate "C" conditions.

T_D = Resistance per ton for Rate "D" conditions.

Ratio of tons and cars with "A" conditions taken as 100.

Grade Percent	$\frac{T_A}{T_B}$	$\frac{T_A}{T_C}$	$\frac{T_A}{T_D}$ *	Grade Percent	$\frac{T_A}{T_B}$	$\frac{T_A}{T_C}$	$\frac{T_A}{T_D}$	Grade Percent	$\frac{T_A}{T_B}$	$\frac{T_A}{T_C}$	$\frac{T_A}{T_D}$
.0	.76	.61		.8	.93	.86	.80	1.5	.96	.91	.87
.1	.82	.68		.9	.93	.87	.82	1.6	.96	.92	.88
.2	.84	.74		1.0	.94	.88	.83	1.7	.96	.92	.88
.3	.86	.77		1.1	.94	.89	.84	1.8	.96	.92	.89
.4	.89	.81		1.2	.95	.90	.85	1.9	.96	.93	.90
.5	.90	.83		1.25	.95	.90	.85	2.0	.97	.93	.90
.6	.91	.84	.76	1.3	.95	.90	.86				
.7	.92	.85	.78	1.4	.95	.91	.87				

FIG. 6—SAMPLE DATA SHEET SHOWING METHOD OF CALCULATING EQUATED TRAIN RESISTANCES IN TONS OF TRAIN.

*On grades of 0.5 per cent. and under the D rate is 90 per cent. of the C rate.

TONNAGE RATING OF ENGINES—AURORA DIVISION

	Class of Engine	R-4 and R-5			
	Diam. of Drivers	69			
	Steam Pressure	210			
	No. of Cars	A	B	C	D
CLYDE TO AURORA	100	1655	1490	1290	1105
	95	1680	1510	1315	1185
	90	1705	1535	1350	1205
	85	1730	1555	1375	1225
	80	1755	1580	1400	1245
	75	1765	1615	1425	1265
	70	1835	1645	1450	1295
	65	1875	1675	1475	1305
	60	1905	1710	1500	1325
	55	1935	1740	1535	1360
	50	1965	1770	1580	1400
	45	1995	1795	1620	1440
	40	2030	1825	1660	1400
	35	2065	1860	1700	1540
	30	.....	.....	1740	1590

	Class of Engine	R-4 and R-5			
	Diam. of Drivers	69			
	Steam Preseure	210			
	No. of Cars	A	B	C	D
SHABBONA TO CLYDE MENDOTA TO CLYDE AURORA TO MENDOTA	100	2060	1785	1610	1450
	95	2095	1815	1635	1470
	90	2130	1845	1665	1500
	85	2165	1875	1695	1525
	80	2200	1905	1725	1555
	75	2233	1935	1765	1590
	70	2270	1970	1795	1615
	65	2300	2000	1830	1645
	60	2335	2025	1865	1080
	55	2370	2055	1905	1715
	50	2410	2090	1945	1750
	45	2450	2125	1080	1780
	40	2490	2160	2020	1820
	35	.....	.....	2060	1855
	30	.....	.....	.....	.....

	Class of Engine	R-4 and R-5			
	Diam. of Drivers	69			
	Steam Pressure	210			
	No. of Cars	A	B	C	D
MENDOTA TO GALESBURG	100	1795	1615	1440	1285
	95	1820	1640	1480	1285
	90	1845	1660	1480	1310
	85	1870	1680	1500	1330
	80	1895	1705	1525	1350
	75	1920	1730	1550	1375
	70	1950	1755	1575	1395
	65	1980	1780	1600	1415
	60	2010	1810	1625	1435
	55	2040	1835	1655	1465
	50	2070	1865	1685	1500
	45	2100	1890	1715	1530
	40	2140	1925	1750	1560
	35	2175	1960	1785	1595
	30	.....	.....	1825	1630

AURORA TO SAVANNA HELPER OREGON TO POLO	100	1250	1130	1050	.....
	95	1265	1140	1060	.....
	90	1280	1150	1075	995
	85	1295	1170	1090	1010
	80	1310	1180	1105	1025
	75	1325	1195	1120	1040
	70	1345	1215	1135	1055
	65	1365	1230	1155	1070
	60	1385	1250	1175	1085
	55	1405	1265	1195	1100
	50	1425	1285	1215	1115
	45	1450	1310	1235	1135
	40	1475	1330	1255	1160
	35	1500	1355	1275	1180
	30	1525	1375	1300	1200
	25	1550	1400	1325	1225
	.....	.....	.....	.....	.....

SAVANNA TO SHABBONA	100	1355	1220	1120	1025
	95	1370	1230	1135	1040
	90	1385	1245	1150	1055
	85	1400	1260	1165	1070
	80	1415	1275	1180	1085
	75	1430	1290	1195	1100
	70	1450	1305	1215	1115
	65	1470	1325	1235	1130
	60	1490	1345	1260	1150
	55	1510	1365	1280	1165
	50	1530	1385	1300	1185
	45	1555	1405	1320	1205
	40	1580	1425	1340	1225
	35	1605	1445	1360	1250
	30	1030	1470	1385	1275
	25	.....	.....	1410	1300
	20	.....	.....	1435	1325

GALESBURG TO MENDOTA	100	1925	1785	1500	1350
	95	1955	1715	1525	1375
	90	1990	1740	1645	1390
	85	2025	1775	1585	1425
	80	2060	1810	1615	1455
	75	2095	1845	1650	1485
	70	2130	1880	1685	1515
	65	2165	1905	1720	1550
	60	2200	1945	1755	1580
	55	2235	1975	1790	1610
	50	2275	2000	1830	1645
	45	2315	2030	1870	1680
	40	2355	2065	1900	1710
	35	2400	2110	1940	1745
	.....	.....	.....	.....	.....
	.....	.....	.....	.....	.....
	.....	.....	.....	.....	.....

RATE "A"—Temp. above 30 degrees F and not much wind.
RATE "B"—Temp. between zero and 30 degrees F., OR strong head or side wind, OR frosty rail.

RATE "C"—Temp. between zero and 30 degrees F AND stroog head or side wiod, OR temp. below zero and not much wind.
RATE "D"—Temp. below zero, with strong side or head wind

FIG. 7—SAMPLE TONNAGE RATES OF AURORA DIVISION OF C. B. & Q. R. R., SHOWN IN TIME CARD, REDUCED SIZE.

EQUATED TONNAGE for .3% GRADE

Resistances 10,000 - 12,500

No. of Cars	10,000				10,500				11,000			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75					760				810			
70	730				785				840			
65	755				815				870	700		
60	785	620			845	680			905	730	610	
55	820	650	555		880	710	595		945	760	640	575
50	855	685	580	520	920	750	625	565	985	795	670	600
45	900	725	610	550	965	795	655	590	1030	840	705	635
40	945	765	650	585	1015	845	695	625	1080	885	745	670
35	995	805	690	620	1065	895	740	665	1135	930	790	710
30	1050	855	735	660	1120	950	790	710	1190	980	840	755
25	1105	905	790	710	1175	1000	840	755	1245	1040	895	805
20	1170	960	845	760	1235	1050	895	805	1305	1100	955	860
15			905	815			950	855			1015	915
10												
5												

No. of Cars	11,500				12,000				12,500			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85					870				925			
80	835				895				950			
75	865				925				980			
70	895	710			955	760			1015	820		
65	930	740			990	790	675		1050	860	715	
60	965	770	655		1030	830	700	630	1090	900	745	670
55	1005	810	685	615	1070	870	730	655	1130	940	775	700
50	1050	850	720	650	1115	910	765	690	1180	980	810	730
45	1095	890	755	680	1165	960	805	725	1230	1030	850	765
40	1150	940	795	715	1220	1000	845	760	1285	1080	895	805
35	1205	990	840	755	1275	1050	895	805	1340	1120	945	850
30	1260	1040	890	800	1330	1100	950	855	1400	1160	1000	900
25	1320	1090	950	855	1390	1160	1010	910	1460	1210	1060	955
20	1380	1140	1010	910			1070	960			1120	1010
15			1070	960			1130	1015				
10												
5												

Note.—Tables showing train resistance from 12,500 to 35,000 lbs are given in Bulletin 138

EQUATED TONNAGE for .4% GRADE

Resistances 10,000 - 12,500

No. of Cars	10,000				10,500				11,000			
	A	B	C	D	A	B	C	D.	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65	615				665				710			
60	640				690				735	625		
55	665	565			710	610			760	650	555	
50	690	590	505		740	635	540		790	675	580	520
45	720	615	530	475	770	660	570	510	820	700	605	540
40	750	640	560	505	800	685	600	540	850	730	635	570
35	785	670	590	530	835	715	630	570	885	760	670	600
30	820	710	625	560	870	750	665	600	920	790	705	630
25	850	750	660	595	910	790	700	630	960	830	740	665
20	900	790	695	625	955	830	740	665	1015	870	780	700
15	960	830	740	665	1015	880	795	715	1075	920	830	745
10			795	715								
5												

No. of Cars	11,500				12,000				12,500			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75					750				795			
70	730				775				820			
65	755				800	670			845			
60	780	660			825	700	605		875		640	
55	805	690	590		855	730	630	560	905	770	665	600
50	835	715	615	550	885	760	655	590	935	800	695	625
45	870	745	645	580	920	790	685	620	970	830	725	650
40	905	775	675	610	955	820	720	650	1005	865	760	685
35	940	810	710	640	990	860	755	680	1040	905	795	715
30	975	850	745	670	1025	900	790	710	1080	950	830	745
25	1015	890	780	700	1070	940	825	740	1125	990	870	780
20	1070	930	825	740	1130	990	870	780	1185	1040	915	825
15			875	785			925	830			970	870
10												
5												

EQUATED TONNAGE for .5% GRADE

Resistances 10,000 - 12,500

No. of Cars	10,000				10,500				11,000			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60									615			
55	560				600				635			
50	580				620	535			655	560	515	
45	600	520	470		640	560	500	450	680	590	530	475
40	625	545	485	435	665	585	520	470	705	620	550	495
35	650	575	505	455	695	615	540	490	735	650	575	615
30	680	605	530	480	725	645	565	510	770	680	600	540
25	715	635	565	510	760	675	600	540	805	710	635	570
20	750	665	600	540	795	705	635	570	840	745	670	600
15	790	700	635	570	835	740	675	610	880	780	710	640
10	830	740	670	600	875	780	715	645			745	670
5												

No. of Cars	11,500				12,000				12,500			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65					675				700			
60	655				695				725	630		
55	675	575			715	610	560		750	650	585	
50	695	600	545		735	630	575	515	775	675	605	545
45	720	625	565	510	760	660	595	535	805	700	625	560
40	750	655	585	525	790	690	615	555	835	730	650	585
35	780	685	610	550	825	720	645	580	870	760	680	610
30	815	720	640	575	860	750	675	605	905	790	715	645
25	850	750	675	605	895	790	710	640	940	830	750	675
20	885	785	710	640	930	830	745	670	975	870	785	705
15	925	825	745	670	970	870	785	705	1015	910	820	740
10			785	705			825	740			855	770
5												

EQUATED TONNAGE for .6% GRADE

Resistances 10,000 - 12,500

No. of Cars	10,000				10,500				11,000			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55									550			
50	500				535				570	500		
45	520	455			555	490			590	520	465	
40	540	475	430		575	510	445		610	540	485	425
35	560	495	445	390	595	530	475		630	560	505	445
30	580	520	460	410	615	550	495	435	655	585	525	465
25	605	545	485	430	640	575	520	460	680	610	550	490
20	635	570	510	450	670	600	545	485	710	635	580	515
15	665	600	545	485	705	630	575	515	745	665	610	545
10	700	630	575	520	740	660	605	550	780	700	640	585
5												

No. of Cars	11,500				12,000				12,500			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60					600				635			
55	585				620				655	575		
50	605	535			640	565	510		675	595	535	
45	625	555	490		660	585	520	460	695	615	550	485
40	645	575	510	450	680	605	540	475	715	635	570	505
35	665	595	530	470	700	630	560	495	740	660	590	525
30	690	620	555	490	725	655	585	515	765	690	615	545
25	720	645	580	515	755	680	610	540	795	715	640	570
20	750	670	610	540	785	705	635	565	825	740	670	595
15	785	700	640	570	815	735	670	595	855	770	705	625
10	820	730	670	610	850	765	705	635			740	660
5												

EQUATED TONNAGE for .7% GRADE

Resistances 10,000 - 12,500

No. of Cars	10,000				10,500				11,000			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55												
50									505			
45	460				490				520	480		
40	470	430			500	460	415		535	490	435	
35	485	445	400	355	515	475	425	380	550	505	450	405
30	505	460	410	370	535	490	435	395	570	520	465	420
25	525	475	430	385	555	505	455	410	595	540	485	440
20	550	495	455	410	580	525	480	435	620	560	510	460
15	575	520	480	435	605	545	505	460	645	585	535	485
10	605	550	505	460	640	580	535	485	670	610	560	510
5			530	485				515				

No. of Cars	11,500				12,000				12,500			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55									575			
50	535				560	500			590	525		
45	550	500			575	520	470		605	545	495	
40	565	515	460	415	590	540	485	435	620	565	515	460
35	585	530	475	430	610	560	500	450	640	585	525	475
30	605	550	490	445	635	580	520	465	665	605	545	490
25	630	570	510	465	660	600	540	485	690	625	565	510
20	655	590	535	485	685	620	565	510	715	650	590	535
15	680	620	560	510	710	645	590	535	740	680	615	560
10	705	650	585	535	740	670	615	560	765	700	640	585
5				560				585				

EQUATED TONNAGE for .8% GRADE

Resistances 10,000 - 12,500

No. of Cars	10,000				10,500				11,000			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55												
50												
45									465			
40	425				450	405			480	435		
35	440	400	360		465	420	385	350	495	450	410	375
30	455	415	375	345	480	435	400	365	510	465	425	390
25	470	430	390	360	495	450	415	380	525	480	440	405
20	490	450	410	375	515	470	435	395	545	500	460	420
15	510	470	430	395	540	490	455	415	570	520	480	440
10	535	490	455	415	565	510	480	440	595	540	505	465
5			480	440			505	465			530	490

No. of Cars	11,500				12,000				12,500			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55												
50					500				525			
45	490				515	470			540	495	450	
40	505	455	415		530	485	440	400	555	505	465	420
35	520	470	430	375	545	500	455	415	570	520	480	435
30	535	485	445	410	560	515	470	430	585	535	495	450
25	550	500	460	425	580	530	490	445	605	550	510	465
20	570	520	480	440	600	550	510	465	625	570	530	485
15	595	545	500	460	625	575	530	485	650	595	550	505
10	625	570	525	485	650	600	555	510	675	620	575	530
5												

EQUATED TONNAGE for .9% GRADE

Resistances 10,000 - 12,500

No. of Cars	10,000				10,500				11,000			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55												
50												
45												
40					405				430			
35	395	355			415	375	350		440	400	375	
30	410	370	345	320	430	390	365	335	455	415	390	360
25	425	385	360	335	445	405	380	345	470	430	405	375
20	440	400	375	350	465	425	395	360	485	450	420	390
15	460	420	395	365	485	445	415	375	505	470	440	405
10	480	440	415	385	505	465	435	395	530	490	460	425
5			435	410								

No. of Cars	11,500				12,000				12,500			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55												
50												
45					460				485			
40	450	410			475	430	400		500	455	420	
35	465	420	395	365	490	445	415	385	515	470	435	405
30	480	435	410	380	505	460	430	400	530	485	450	420
25	495	450	425	395	525	480	445	415	550	500	465	435
20	515	470	440	410	545	500	465	430	570	520	485	450
15	535	490	460	425	565	520	485	450	590	540	505	470
10	555	510	480	445	585	540	505	470	610	560	525	490
5												

EQUATED TONNAGE for 1.0% GRADE

Resistances 10,000 - 12,500

No. of Cars	10,000				10,500				11,000			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55												
50												
45												
40												
35	360				380	355			400	375		
30	370	340	320	300	390	365	335	315	415	385	355	335
25	380	350	330	310	405	375	345	325	430	395	365	345
20	395	365	340	320	415	385	360	340	445	410	380	360
15	410	380	355	335	435	405	375	355	460	425	395	370
10	430	400	375	350	455	425	395	370	480	445	415	390
5			395	370				390				

No. of Cars	11,500				12,000				12,500			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55												
50												
45												
40	405				435	400			455	420		
35	420	390	365		445	410	385	360	465	430	400	375
30	435	400	375	350	460	425	395	370	450	445	410	385
25	450	415	385	360	475	440	410	380	495	460	425	395
20	465	430	400	375	490	455	425	395	510	475	440	410
15	485	450	415	390	510	475	440	410	530	495	460	435
10	505	470	435	410	530	495	460	430	550	515	480	450
5												

EQUATED TONNAGE for 1.1% GRADE

Resistances 10,000 - 12,500

No. of Cars	10,000				10,500				11,000			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55												
50												
45												
40												
35					350				370			
30	340	315			360	335			380	355	330	305
25	350	325	305	280	370	345	325	300	395	370	345	320
20	365	340	320	295	385	360	340	315	410	385	360	335
15	380	355	325	310	400	375	355	330	425	400	375	350
10	395	370	350	325	415	390	370	345	440	415	390	365
5												

No. of Cars	11,500				12,000				12,500			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55												
50												
45												
40					400				420			
35	390	360			410	380			430	400	380	355
30	400	370	350	325	420	390	370	345	440	410	390	365
25	415	385	365	340	435	405	380	355	455	425	400	375
20	430	400	380	355	450	420	395	370	470	440	415	390
15	445	415	395	370	465	435	410	385	485	455	430	405
10	460	430	410	385	480	450	425	400	500	470	445	420
5												

EQUATED TONNAGE for 1.2% GRADE

Resistances 10,000 - 12,500

No. of Cars	10,000				10,500				11,000			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55												
50												
45												
40												
35												
30	315				330	310			350	330	310	
25	325	305	285	270	340	320	300	285	360	340	320	300
20	335	315	295	280	355	330	310	295	375	355	330	310
15	350	330	310	290	370	345	325	305	390	370	345	320
10	365	345	325	305	385	360	340	320	405	385	360	335
5	380	360	340	320	400	375	355	335	420	400	375	350

No. of Cars	11,500				12,000				12,500			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55												
50												
45												
40												
35	360				380	355			395	370		
30	370	350	325	305	390	365	345	325	405	380	360	340
25	380	365	335	315	400	375	355	335	420	395	370	350
20	395	370	345	325	415	390	365	345	435	410	380	360
15	410	385	360	335	430	405	380	355	450	425	395	370
10	425	400	375	350	445	420	395	370	465	440	410	385
5	440		395	370			415	390			425	400

EQUATED TONNAGE for 1.25% GRADE

Resistances 10,000 - 12,500

No. of Cars	10,000				10,500				11,000			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55												
50												
45												
40												
35									330			
30	305				325	305			340	320	300	280
25	315	295	280	260	335	315	295	275	350	330	310	290
20	325	305	290	270	345	325	305	285	360	340	320	300
15	335	315	300	280	355	335	315	295	370	350	330	310
10	350	330	315	290	370	350	330	305	385	365	345	320
5	370	350	330	305	385	365	345	320	400	380	360	335

No. of Cars	11,500				12,000				12,500			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55												
50												
45												
40												
35	350				365	350			385	365		
30	360	340	320		375	360	335	310	395	375	355	325
25	370	350	330	305	385	370	345	320	405	385	365	335
20	380	360	340	315	395	380	355	330	415	395	375	345
15	390	370	350	325	410	390	365	340	430	410	385	355
10	405	385	365	335	425	405	380	355	445	425	400	370
5	420	400	380	350			400	370				385

EQUATED TONNAGE for 1.3% GRADE

Resistances 10,000 - 12,500

No. of Cars	10,000				10,500				11,000			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55												
50												
45												
40												
35												
30					305				325	305		
25	300	285	265	250	315	300	280	265	335	315	295	280
20	310	295	275	260	325	310	290	275	345	325	305	290
15	320	305	285	270	335	320	300	285	355	335	315	300
10	335	320	300	285	350	335	315	300	370	350	330	315
5									385	370	345	330

No. of Cars	11,500				12,000				12,500			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55												
50												
45												
40												
35					355				370	350		
30	345	325			365	345	320	305	380	360	335	320
25	355	335	310	295	375	355	330	315	390	370	345	330
20	365	345	320	305	385	365	340	325	400	380	355	340
15	375	355	330	315	395	375	350	335	410	390	365	350
10	390	370	345	330	410	390	365	350	425	405	380	365
5	405	385	360	345			380	365			395	380

EQUATED TONNAGE for 1.4% GRADE

Resistances 10,000 - 12,500

No. of Cars	10,000				10,500				11,000			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55												
50												
45												
40												
35												
30									305			
25	285	270	255		300	285	270		315	300	280	265
20	295	280	265	250	310	295	280	265	325	310	290	275
15	305	290	275	260	320	305	290	275	335	320	300	285
10	315	300	285	270	330	315	300	285	350	330	315	300
5	325	310	295	280	345	330	310	295	365	345	330	315

No. of Cars	11,500				12,000				12,500			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55												
50												
45												
40												
35												
30	320	305			340	320	305		355	335	320	
25	330	315	295	280	350	330	315	300	365	345	330	315
20	340	325	305	290	360	340	325	310	375	355	340	325
15	350	335	315	300	370	350	335	320	385	365	350	335
10	365	345	330	315	385	365	350	335	400	380	365	350
5	380	360	345	330	400	380	365	350	415	395	380	365

EQUATED TONNAGE for 1.5% GRADE

Resistances 10,000 - 12,500

No. of Cars	10,000				10,500				11,000			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55												
50												
45												
40												
35												
30												
25	265	255			280	265	250		295	280	265	250
20	275	265	250	245	290	275	260	255	305	290	275	260
15	285	275	260	250	300	285	270	260	315	300	285	270
10	295	285	270	260	310	295	280	270	325	310	295	280
5	310	295	280	270	325	310	295	280	340	325	310	295

No. of Cars	11,500				12,000				12,500			
	A	B	C	D	A	B	C	D	A	B	C	D
100												
95												
90												
85												
80												
75												
70												
65												
60												
55												
50												
45												
40												
35												
30	305				320	305			330	315		
25	310	295	280	260	325	310	295	275	340	325	310	290
20	320	305	290	270	335	320	305	285	350	335	320	300
15	330	315	300	280	345	330	315	295	360	345	330	310
10	340	325	310	290	355	340	325	305	375	355	340	320
5	355	340	320	305	370	355	335	320	390	370	355	335

THE STORAGE BATTERY IN RAILWAY SERVICE.

(Bulletin 145.)

By L. C. Fritch, Chief Engineer, Chicago Great Western Railroad.

INTRODUCTORY.

The Storage Battery is rapidly coming into prominent use in various operations in railway service, such as Train Lighting, Station Lighting, Signaling and Interlocking, Operation of Drawbridges, Motor Truck and Motor Car Propulsion, Telephone and Telegraph work, Supplementing the Load on Current Supply Systems, and numerous other uses to which it is readily adapted.

A brief outline of the theory and principal characteristics of the storage battery is herein submitted with the thought that it will prove of some service to the Engineer in solving the problems that daily confront him in his work. An effort has been made to present the subject in an elementary form and as briefly as consistent, and although the entire subject is not fully treated, it embodies the essential features of a branch of the electrical field which is daily becoming more and more important in railway operation.

HISTORY.

The principle of the Storage Battery has been known for over one hundred years. Gautherot in 1801 discovered that a secondary current could be obtained from a cell which consisted of two silver or platinum electrodes immersed in a common salt solution.

The cell was first charged by passing a current through it, then breaking the charging current; he connected the two electrodes to the terminals of a galvanometer and obtained a momentary deflection, indicating a flow of current in a direction opposite to the charging current.

While the discovery of the principle of the storage, or secondary, battery may be said to date from 1801, no further development of note was made in its application to practical use until 1842, when Sir William Grove constructed a gas battery, which established the first progress toward a commercial accumulator.

Grove's battery consisted of a pair of platinum strips immersed in dilute sulphuric acid, each strip being surrounded on top and sides by a closed glass tube, which collected the gas developed in charge, and kept

each gas in contact with its respective electrode and some of the adjoining acid surface. After a charge was passed through this battery and its terminals, then connected with a galvanometer, a small current in reverse direction was perceived for some time, until the oxygen and hydrogen developed by the charge gradually became absorbed by the platinum and recombined to form water. While this was an important advance over the discovery of Gautherot, it resulted in no practical value, and with all the development since Grove's time it has failed of commercial value.

In 1860 Planté, a Frenchman, developed the next important step in storage battery development, which was destined to prove of great commercial value. His experiments consisted in making a cell using lead strips instead of platinum, immersed in dilute sulphuric acid. This cell on being charged yielded a considerable reverse, or "secondary," current. Planté's important discovery was that each time such a cell was charged and discharged the quantity of "secondary" current increased, and further experiments developed that, not merely discharging, but charging in the reverse direction each time, the capacity was brought up rapidly. By these discoveries batteries of sufficient capacity to render them commercially valuable were produced. The subsequent developments and changes made in the Planté type of battery have been along the same fundamental lines, so that to Planté must be accorded the honor of first having developed a commercially practicable storage, or secondary, battery.

Planté found that the lead plate which was connected to the negative pole of the primary source of power became coated with a film of dark brown peroxide of lead, and the lead plate connected with the positive pole was coated with spongy, metallic lead. Each time the charging current was reversed, more of the metallic lead became peroxidized and the gradual accumulation of this film of "active material" on both plates caused the increased capacity of the cell.

Planté arranged a large series of cells, through which he continually passed a current, first in one direction and then in the reverse, the duration of charge gradually increasing, and by this process the plates accumulated considerable thickness, respectively, of active porous lead and lead peroxide on their surfaces. After one to two months of this formative process, the plates were ready for use.

The "forming" process for converting solid lead into active material was tedious and expensive, and the next progress made consisted in overcoming this difficulty. Planté's experiments were made during a time when electricity had limited uses, and not until the dynamo was perfected was the urgent necessity of storage batteries imminent.

In 1881 Faure, another Frenchman, discovered a process of forming the plates of batteries without the tedious and expensive process used by Planté. Instead of electro-chemically treating the surface of the metallic lead plate, Faure covered the surface with lead oxide in the first instance. A single charge was then sufficient to convert this into lead

peroxide on the one plate and metallic lead upon the other. This invention marked the last stride toward the perfection of the storage battery for practical use.

At the same time and working entirely independently of Faure, Brush, in America, arrived at the same results as did Faure, so that in this country we give to Brush the honor of producing the battery known as the "pasted plate" battery.

All lead battery plates made at the present time are either after the Planté type, where part of the metallic lead plate is chemically acted upon to produce the active material, or else after the Brush-Faure, or pasted type, where the active material, usually in the form of an oxide of lead, forms an integral part of the original plate.

Great improvement, however, has been made in details of design, construction and process of manufacture, which have collectively brought the lead battery up to a high state of perfection and of great commercial importance and value.

About ten years ago Thomas A. Edison assigned himself the task of perfecting a new type of storage battery, one that would be light, durable and compact and free from the difficulties inherent in the lead-sulphuric acid battery. After nearly ten years of unremitting toil, repeated failures and triumphs and at the expenditure of vast sums of money, he has succeeded in perfecting a type of battery which is a distinct departure from the old battery practice.

The principle of electro-chemical action in the active materials is the same as in any other type of "secondary" battery, but instead of using lead plates and sulphuric acid as an electrolyte, Edison uses steel plates, nickel plated, with steel tubes and pockets, respectively, to contain the active material in the positive and negative plates, the active material consisting of nickel hydrate for the positive plate, and iron oxide for the negative plate, and the electrolyte being a solution of about 21 per cent. of potassium hydrate and a small percentage of lithia.

The use of these elements provides a combination that is practically free from the corrosive effects of the lead-sulphuric acid batteries.

The Edison battery has now been in commercial use about three and one-half years, and sufficient length of time has hardly elapsed to determine its life and efficiency, as far as economy of cost is concerned, compared with the lead battery, which latter has been in practical use for upwards of thirty years.

THE LEAD-SULPHURIC ACID STORAGE BATTERY.

THE PRINCIPLES OF THE STORAGE BATTERY.

The function of a storage battery in transforming the energy of chemical combination into electrical energy is practically the same as that of a primary battery. The storage battery has the additional property of being able to be recharged by the passage of a current in the

reverse direction through the cell. This reversal of current reverses the chemical reactions which had taken place during the discharge, and restores the cell to its original condition.

THE LEAD CELL.

Until quite recently the only type of cell that has been extensively adopted in commercial service of all kinds is the lead cell. This cell consists of two lead plates or two groups of such plates which constitute, respectively, the positive and negative electrodes, immersed in a solution of dilute sulphuric acid. Each plate consists of a metallic support, or grid, which acts as a support for the active material, and at the same time serves to conduct the electric current to the point where connection is made to the external circuit. The active material of the positive plate, when fully charged, consists of lead peroxide represented by the symbol PbO_2. This lead peroxide in a healthy cell has a dark chocolate brown color. The active material of the negative plate in a fully charged cell is spongy metallic lead, and is slate gray in color. During discharge the peroxide is reduced to a lower state of oxidization and combines with a portion of the sulphuric acid in the electrolyte forming lead sulphate ($PbSO_4$), which being insoluble remains on the plate. At the same time the spongy metallic lead of the negative plate becomes oxidized, and also combines with a portion of the sulphuric acid of the electrolyte, forming sulphate of lead on the negative plate. During discharge, therefore, it will be seen that the electrolyte loses some of its sulphuric acid, and becomes weaker. When the cell is recharged the lead sulphate on the two plates is decomposed, the sulphuric acid is restored to the electrolyte, while the active material on the positive plate again becomes lead peroxide, and on the negative plate spongy metallic lead.

The chemical action above described may be expressed in the form of the following equations:

$$PbO_2 + H_2SO_4 = PbSO_4 + H_2O + O \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$Pb + H_2SO_4 = PbSO + H_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$(1) + (2) = PbO_2 + Pb + 2H_2SO_4 = 2PbSO_4 + 2H_2O \quad \ldots\ldots\ldots (3)$$

Equation (1) represents the reactions which take place at the positive plate, and equation (2) at the negative plate during charge, and equation (3) the combined effect or fundamental equation of the storage battery and is the reaction which takes place on discharge.

CHARACTERISTICS OF THE LEAD CELL.

The open circuit voltage of the lead storage cell is from 2.05 to 2.1 volts. This applies to a cell which has been allowed to stand for a sufficient length of time on open circuit to acquire its true voltage reading. Immediately after charging a cell, its open circuit voltage will be somewhat higher, due to bubbles of hydrogen and oxygen gas retained in the plates, as well as to concentration of acid in the pores of the plates. Immediately after discharge especially at high rates, the open

circuit voltage will be somewhat low, owing to the exhaustion of acid in the pores of the plates. After standing for some time, the open circuit voltage is gradually restored to the normal value, and this occurs whether the cell is fully charged or is considerably discharged. The open circuit voltage of a cell cannot, therefore, be used as an indication of the state of charge of the cell.

During discharge the voltage of a cell will drop below its open circuit value, this drop being due to two different causes, namely, the internal resistance of the cell, whose effect is instantaneous, and the so called polarization, which appears more gradually. This drop in voltage increases as the cell becomes more nearly discharged. It varies with the rate of discharge, and with the temperature. The final voltage at the end of a discharge at the normal or eight-hour rate will be approximately 1.75. At higher rates it will be somewhat lower.

During charge, the voltage of the cell will rise above the open circuit voltage by an amount dependent also upon the rate of charge, and the temperature. During charge at normal rate the voltage of the cell gradually rises, varying from about 2.15 to 2.3 volts, and toward the end of the charge this voltage rises rapidly until it reaches a maximum, which may be anywhere from 2.5 to 2.8 volts, depending upon the rate, temperature, acid density, and age of the cell. On account of these variations, the actual cell voltage is not a satisfactory indication of the completion of the charge. The most reliable way of determining when a cell is fully charged is to continue the charging current at constant rate until the cell voltage and the specific gravity of the electrolyte cease to increase and become constant. (Fig. 1.)

The capacity of a storage battery cell is usually stated in ampere hours, based upon a rate of discharge which will exhaust the cell in a period of eight hours. This rate is called the normal rate, and the capacity which the cell will give at this rate in ampere hours is called the normal capacity. The capacity of a cell in ampere hours is decreased by increasing the rate of discharge, so that a cell which will give 20 amperes for eight hours, or 160 ampere hours, will give 40 amperes for about three hours, or 120 ampere hours, and will give 80 amperes for one hour, or 80 ampere hours. The relations between the discharge rate and the capacity given above are approximate, and vary somewhat with the design of the cell and the type of plate. A rating of seven hours at the normal rate and one hour at four times the normal rate is quite usual. (Fig. 2.)

The capacity of a cell in ampere hours is also affected by the temperature, and in the vicinity of 70 degrees F. the normal capacity is reduced about 6/10 of 1 per cent. for a reduction of one Fahrenheit degree, but the capacity also increases with rise in temperature at about same rate.

During discharge, as noted above, the acid density becomes reduced owing to the combination of the sulphuric acid with the active mate-

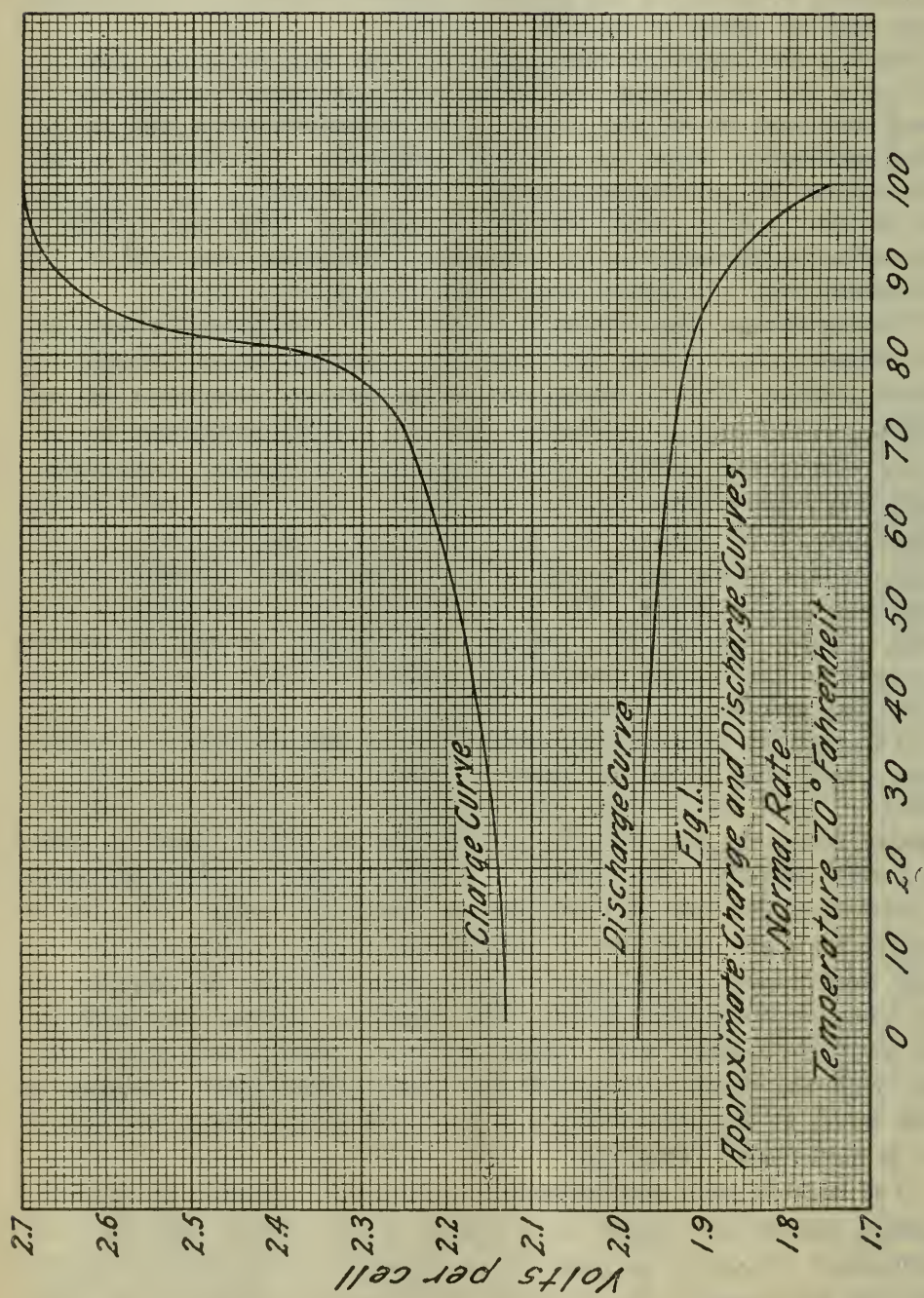

Volts per cell
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
Time in per cent total
0
10
20
30
40
50
60
70
80
90
100
Charge Curve
Discharge Curve
Fig. 1.
Approximate Charge and Discharge Curves
Normal Rate
Temperature 70° Fahrenheit

FIG. 1.

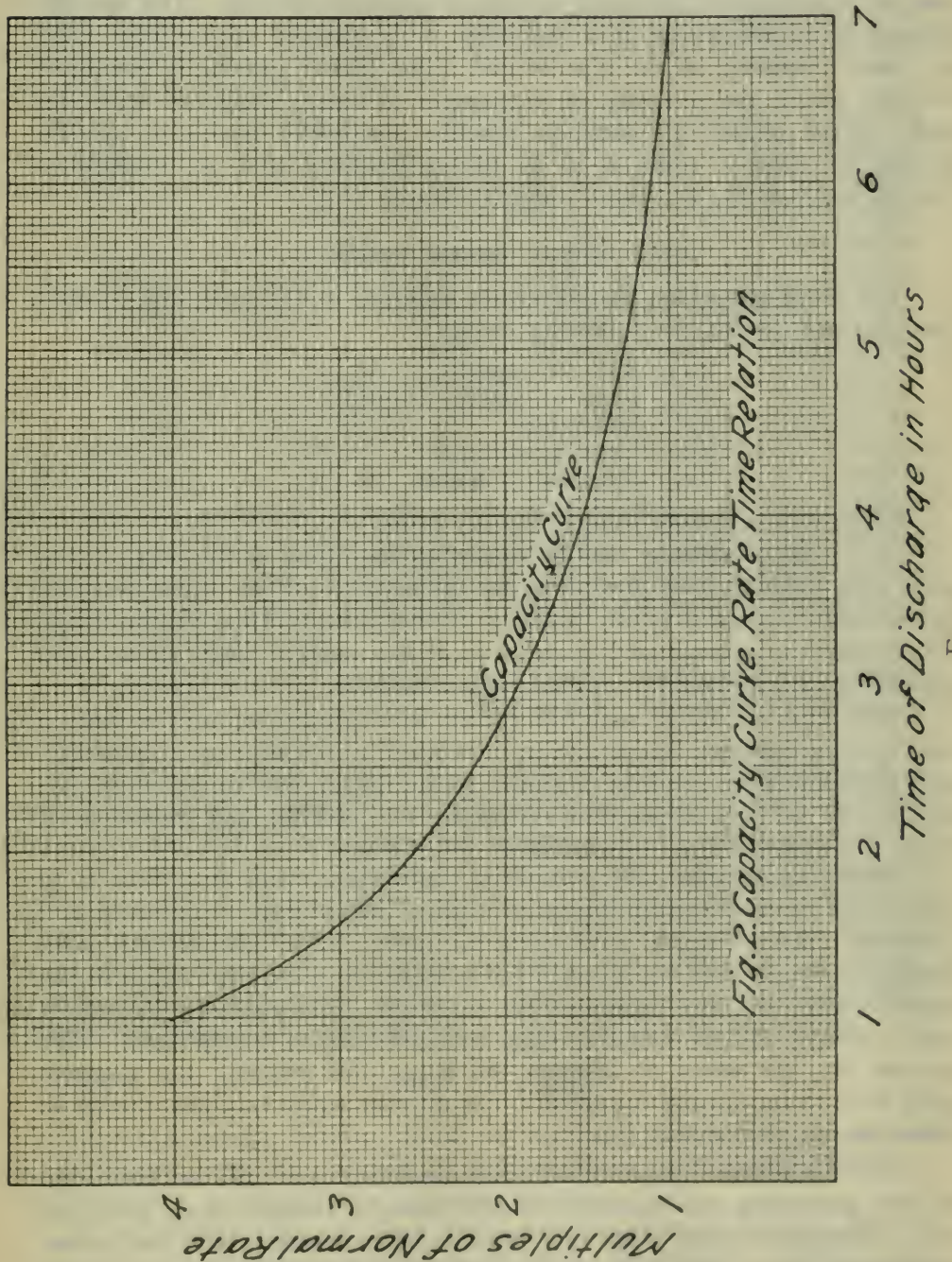

Capacity Curve
Fig. 2. Capacity Curve. Rate Time Relation
Time of Discharge in Hours
1
2
3
4
5
6
7
Multiples of Normal Rate
4
3
2
1

FIG 2.

rial of the plates. The variation in the density of the electrolyte is, therefore, a very accurate measure of the state of charge of a cell, provided proper correction is made for temperature, and for the loss of water due to evaporation, provided also that a sufficiently free circulation of electrolyte is secured to insure uniform density. The specific gravity of the electrolyte in a cell when fully charged varies from 1.200 to 1.300, depending on the type of cell. The higher gravity is employed in cells where the quantity of electrolyte is small compared with the bulk of the plates. In common practice electrolyte having a specific gravity of 1.200 is referred to as twelve hundred acid, or sometimes, though erroneously, as twelve hundred degree acid.

LEAD BATTERY CHARACTERISTICS.

The more important characteristics inherent in the operation of lead batteries are due to the following causes:

(a) Loss of capacity.
(b) Loss of active material.
(c) Sulphation.
(d) Loss of voltage.
(e) Buckling of plates.

These will be briefly treated in their order.

(a) Loss of capacity may be caused by the filling of the pores in the plate with sulphate, thus preventing the taking place of the proper reaction in the active material in the interior of the plates. This condition can be remedied by a prolonged overcharge at low current rates, or at from one-fourth to one-half the normal eight-hour rate.

(b) Loss of active material occurs to a greater or less extent in lead storage batteries, but is greatly increased by frequent over-discharge, and the amount of sulphate deposited in the plates will cause undue expansion of the active material, resulting in cracking and shedding of same and depositing at the bottom of the plates.

When the negative active material contracts to such an extent as to reduce the capacity perceptibly, the positive plates may be removed and "dummy" plates (lead sheets) substituted. The connections with terminals should then be reversed. The negative plate then becomes the positive plate and the "dummy" the negative. The charging current is then reversed and the negative plate changed back to sponge lead. This process has the effect of opening the pores and bringing the negative plate back to its normal condition. The current when reversed should be about double the normal rate.

(c) Sulphation results from over-discharge and can be prevented by not permitting the discharge to fall below a voltage of 1.8 volts per cell. Sulphation takes place very rapidly when a battery has been over-discharged and is permitted to stand idle in this condition before charging.

The treatment for sulphation consists in charging a battery as rapidly as possible without overheating. As the resistance of the cell is greatly

increased by the sulphate deposited on the plates, it will become hot. The temperature should not exceed 110 degrees Fahrenheit. When the plates begin to gas freely reduce the rate of charge to normal and continue until gassing again takes place. The rate of charge should then be reduced to about one-half the normal rate and continued until further gassing occurs. The cells should then be partly discharged and the process repeated. Several cycles of this treatment may be required until the capacity of the cells is restored.

(d) Loss of voltage is due directly to loss in capacity of one or more cells. The cells having the lower capacity, being in series with the main battery, will discharge at the same rate as the cells of higher capacity, causing the voltage of the former to drop more rapidly, bringing them below those of higher capacity. The remedy lies in bringing up the capacity of the lower cells by treatment for the causes which induced the loss of capacity, by treating the lower cells specifically.

(e) Buckling of plates is due to the over-expansion of the plates on discharge, and is caused by sulphation to such an extent as to cause expansion of the plates beyond their safe limit. This difficulty results from over-discharge and consequent excess deposit of sulphate on the plates, and is intended to be provided against in the construction of the plates, but when this expansion exceeds a safe limit, buckling of plates results. Buckling may also result from rapid charging or discharging, causing unequal distribution of electro-chemical action on two surfaces of the plate and thereby setting up stresses, which, if not resisted by the plate, result in distorting them.

The remedy against buckling of plates lies in well constructed plates, and care in not over-discharging, or too rapidly charging or discharging batteries.

(f) Loss of electrolyte is a frequent cause of loss of capacity in batteries. If through evaporation or other causes the level of the electrolyte falls below the top of the plates, the portion exposed performs no function, and the surface of the active material for the electro-chemical action is reduced, cutting down the capacity of the cells. The remedy lies in keeping the level of the electrolyte above the top of the plates. When adding electrolyte, care must be taken not to increase its specific gravity. The added portion should be either pure water or a very dilute solution of about 5 per cent. of acid and 95 per cent. of pure water.

TYPES OF PLATES.

The lead storage battery plates are divided broadly into two classes in accordance with the process of manufacture, namely, the Planté or formed plates, and the Faure or pasted plates.

In the Planté type of plate the active material is formed electro-chemically out of the metal of the grid itself. In order to obtain a satisfactory formation, it is necessary that the grid should be practically of pure lead. In order to obtain a sufficient extent of surface on which to produce this formation of active material, the lead grid is sometimes

provided with leaves or ribs extending across its face, which may be produced either by rolling, spinning or cutting the original lead blank; or a cast grid may be produced consisting of vertical and horizontal ribs with openings extending entirely through the plate. The latter type of grid, having no central web, has the advantage, when used as a positive, of permitting the active material to be worked uniformly throughout, even though the amount of work on opposite sides of the plate is unequal, whereas with a positive plate having a central web, unequal work on opposite sides (a condition which is almost sure to occur, due to difference in separation, or in the capacity of adjacent plates) will discharge one side of the plate before the other, producing unequal expansion and contraction of the active material, and a tendency to distortion called "buckling." This does not apply to the negative plate, as its active material does not expand and contract appreciably in normal service. (Figs. 3 and 4.)

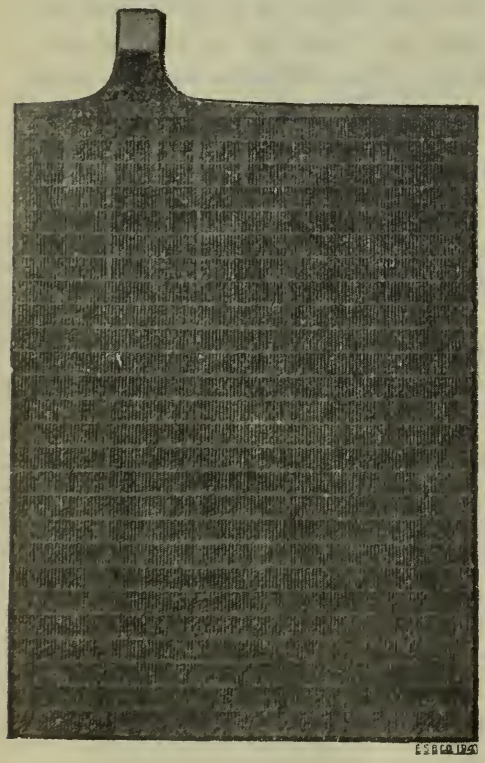


FIG. 3. TUDOR POSITIVE PLATE, TYPE "EP."

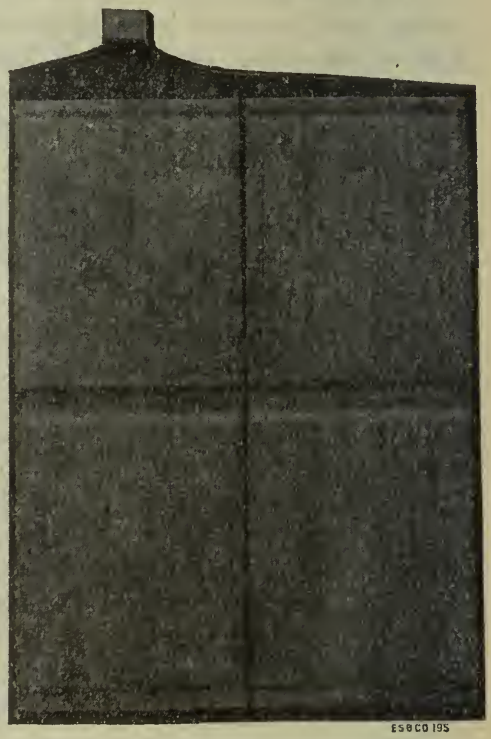


FIG. 4. ROLLED NEGATIVE PLATE, TYPE "EP."

In addition to these pure lead grids, composite Planté plates have been extensively used for the positive plate, consisting of a grid or frame of hard antimony lead alloy, supporting sections or buttons of soft lead on which the active material is formed. The best known plate of this type is the Manchester plate in which the buttons are made of pure lead ribbon corrugated crosswise, and rolled up into rosettes which are forced into circular openings in the alloy grid. The active material

is then formed on the surface of the corrugations of the ribbon. This latter type of composite Planté plate has been used only for the positive plate, while the pure lead Planté plates are used for both positive and negative plates. (Fig. 5.)

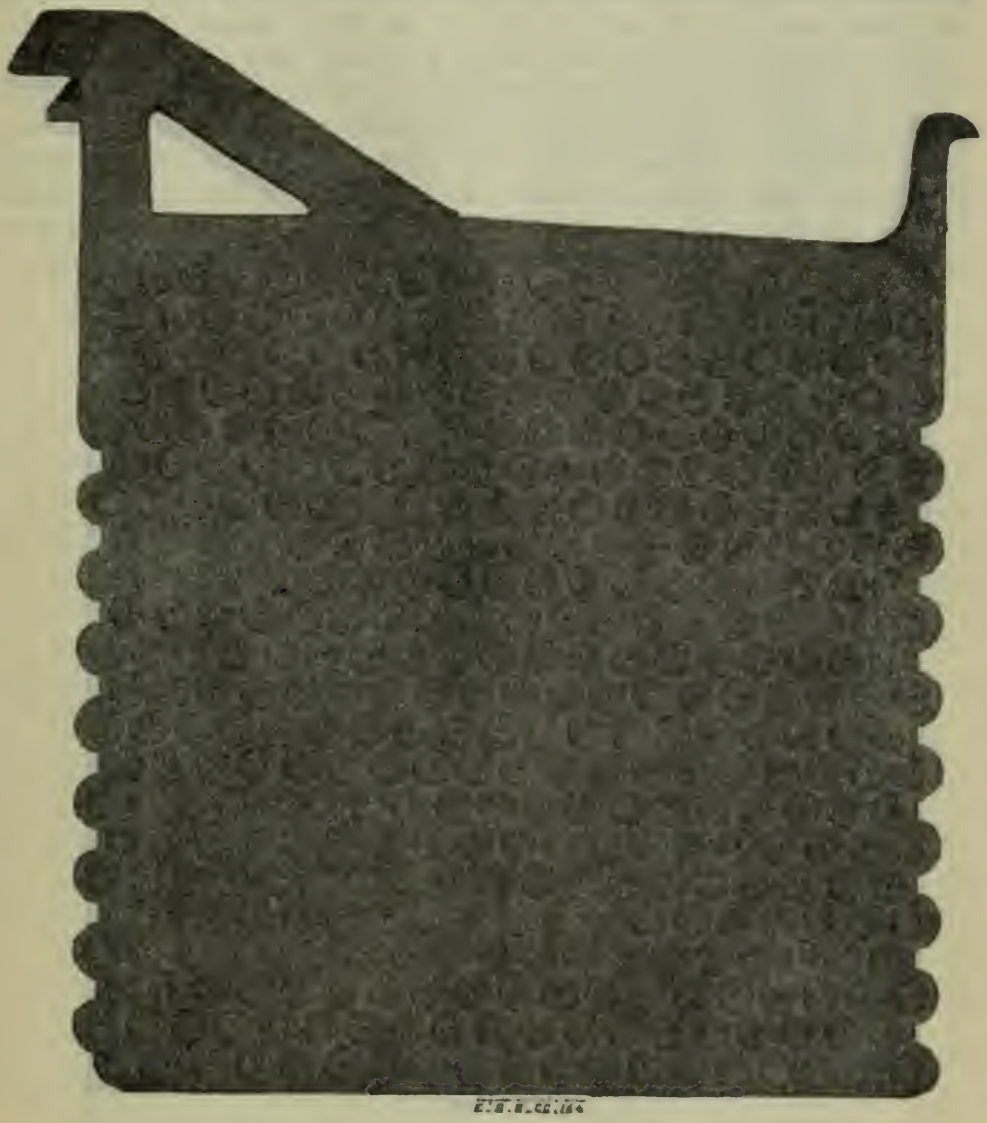


FIG. 5. MANCHESTER POSITIVE PLATE.

Rigid Grid, impervious to the action of the electrolyte, thus insuring original conductivity and mechanical support for the active material throughout the life of the plate.

Growth of the active material does not distort the plate, but increases the contact pressure between the buttons and the grid.

Absence of a central web prevents buckling or other injury due to any unequal work on opposite sides of the plate.

The Faure or pasted plate consists of an antimony lead alloy grid, to which is mechanically applied, by a process called "pasting," the active material consisting principally of oxide of lead with small quan-

tities of other ingredients, applied in the form of a paste. After drying, the active material is either reduced, or formed to the higher oxide, to produce the negative or positive plate, respectively. Many designs of grids have been brought out for such pasted plates, the principal object

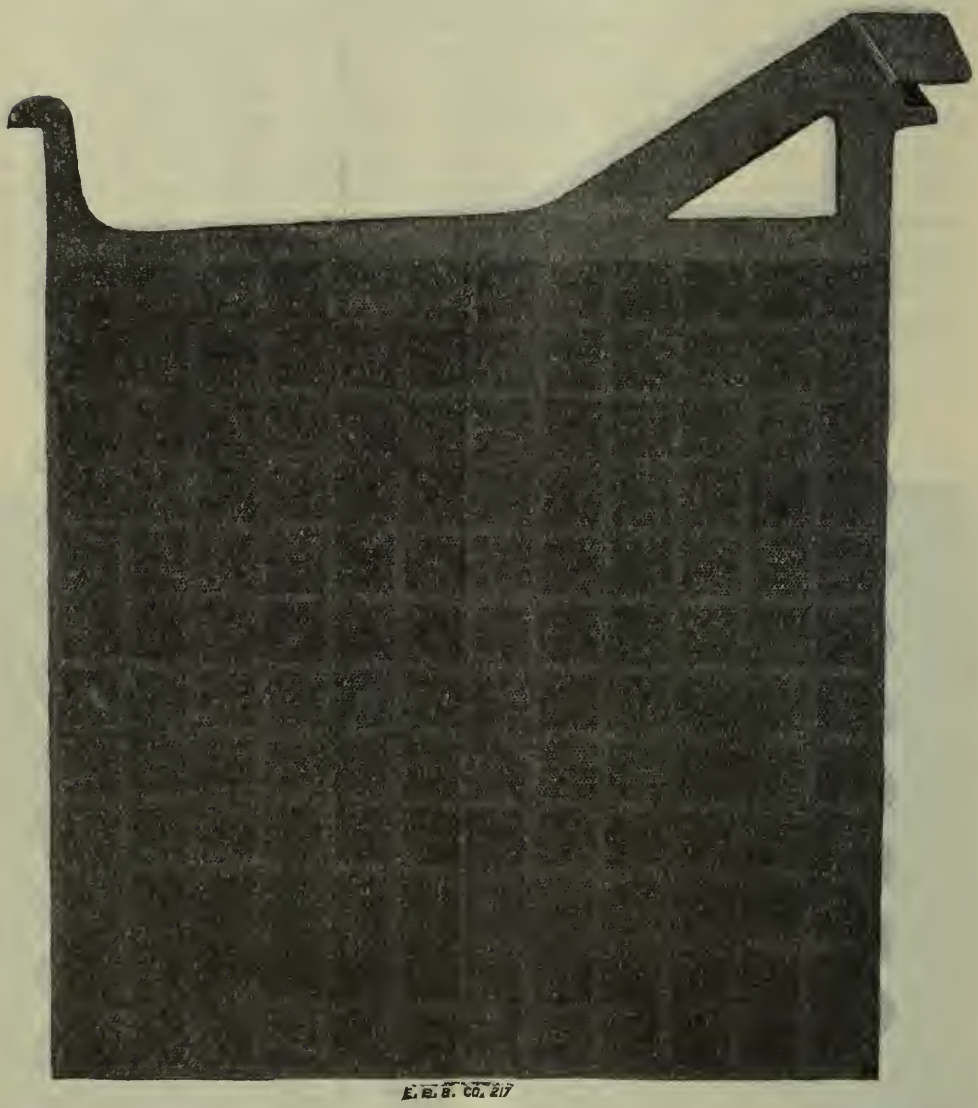


FIG. 6. BOX NEGATIVE PLATE.

Rigid Grid, impervious to the action of the electrolyte, thus insuring original conductivity and mechanical support for the active material throughout the life of the plate.

Active material enclosed in compartments by perforated sheet lead. Thus, the active material need not be mechanically self-supporting, but is of a permanent porous composition best adapted to the electro-chemical requirements of the negative plate.

usually being to arrange ribs or pockets that will retain the active material in position, and at the same time maintain good contact between the active material and the metal support. (Figs. 6 and 7.)

CONTAINING VESSELS.

Three kinds of containing vessels are used for storage battery cells, namely, glass jars, lead-lined wooden tanks and hard rubber jars. Glass jars are used for stationary batteries of smaller capacity up to capacities of about 800 ampere hours at the normal rate. It has been found impossible to obtain glass jars on a commercial scale for batteries of larger sizes owing to the excessive breakage, due to the weight of plates and electrolyte and to expansion and contraction with changes of temperature. For stationary batteries of larger capacity, therefore, lead-lined wooden tanks are used. It has been found that selected long leaf yellow pine is a very durable wood for these tanks on account of its acid-resisting qualities. Special precautions are also taken in the design of

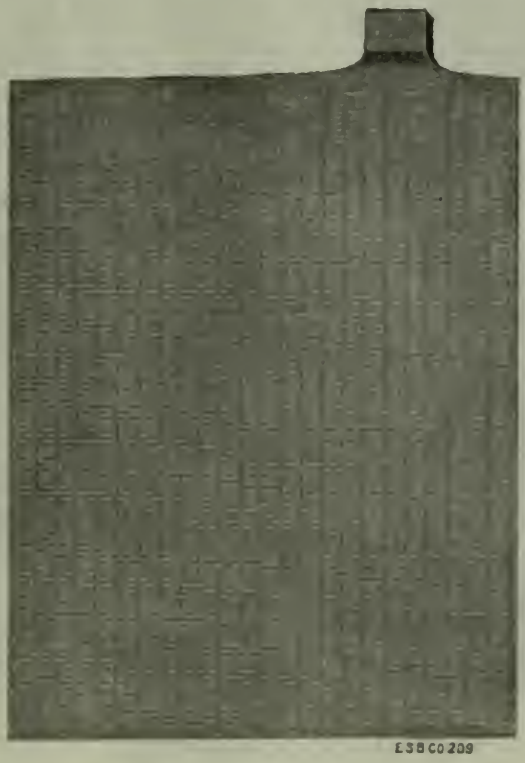


FIG. 7. SHELF NEGATIVE PLATE.

these tanks to keep the acid away from the wood. These precautions consist in carrying the lead lining up over the upper edges of the tank, and down a short distance on the outside clear from the tank; these overhanging edges being provided with drip points to concentrate any dripping due to the creeping of the acid, where it will do no harm. Rubber jars are used for portable cells on account of their lightness. (Figs. 8, 9 and 10.)

The plates in stationary batteries are supported by plate lugs projecting from the plates near the top, which rest upon the edges of glass jars or upon vertical sheets of glass in lead-lined tanks. This leaves

a free space beneath the plates for sediment to collect without the possibility of short-circuiting the plates; this space being free from obstructions which would interfere with the removal of this sediment, and this must be done at intervals of several years in most stationary batteries. In rubber jars the plates are supported on ribs moulded into the bottom of the jar. These ribs must be made of sufficient height to provide ample sediment space.

In stationary batteries, where there is ample separation between the plates in a cell, wood diaphragm separators supported by vertical slotted dowels are installed between adjacent plates. (Fig. 11.) In the larger

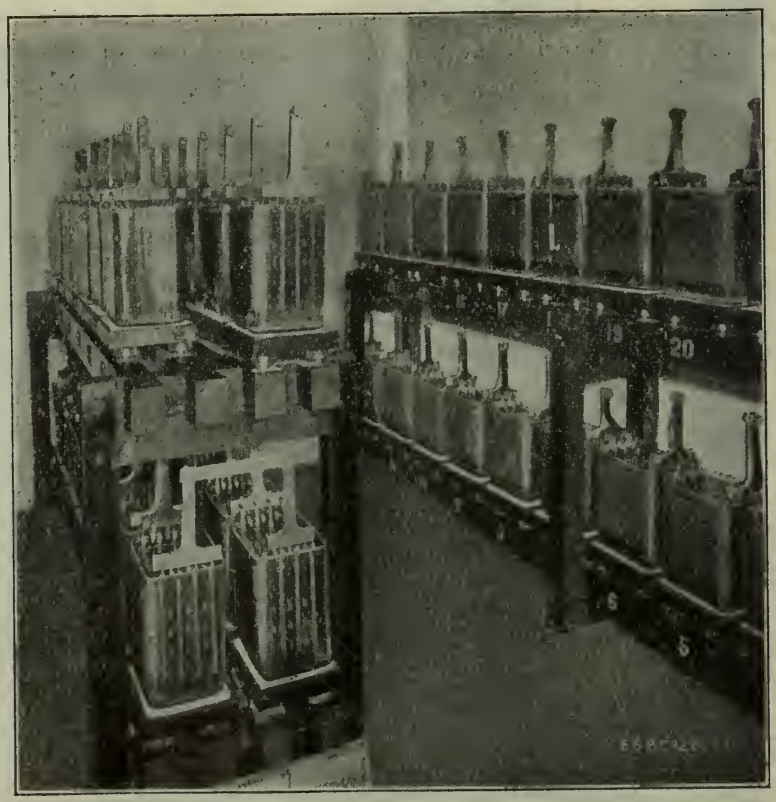


FIG. 8. MULTIPLE-PLATE TYPE "CHLORIDE ACCUMULATOR" INSTALLED ON TWO TIER RACKS IN AN OUTBUILDING.

cells hard rubber pins through the dowels near the top serve to support them from the tops of the plates. In smaller cells the dowels extend to the bottom of the jar. The dowels prevent the plates from coming in contact with the separator, and the separator prevents the growth of so-called lead trees between adjacent plates which might produce short-circuits. In portable cells where the plate separation is reduced to a minimum no dowels are used, but a perforated sheet of hard rubber is usually inserted between the positive plate and the wood separator on either side to avoid the destructive action of the lead peroxide on the wood separator.

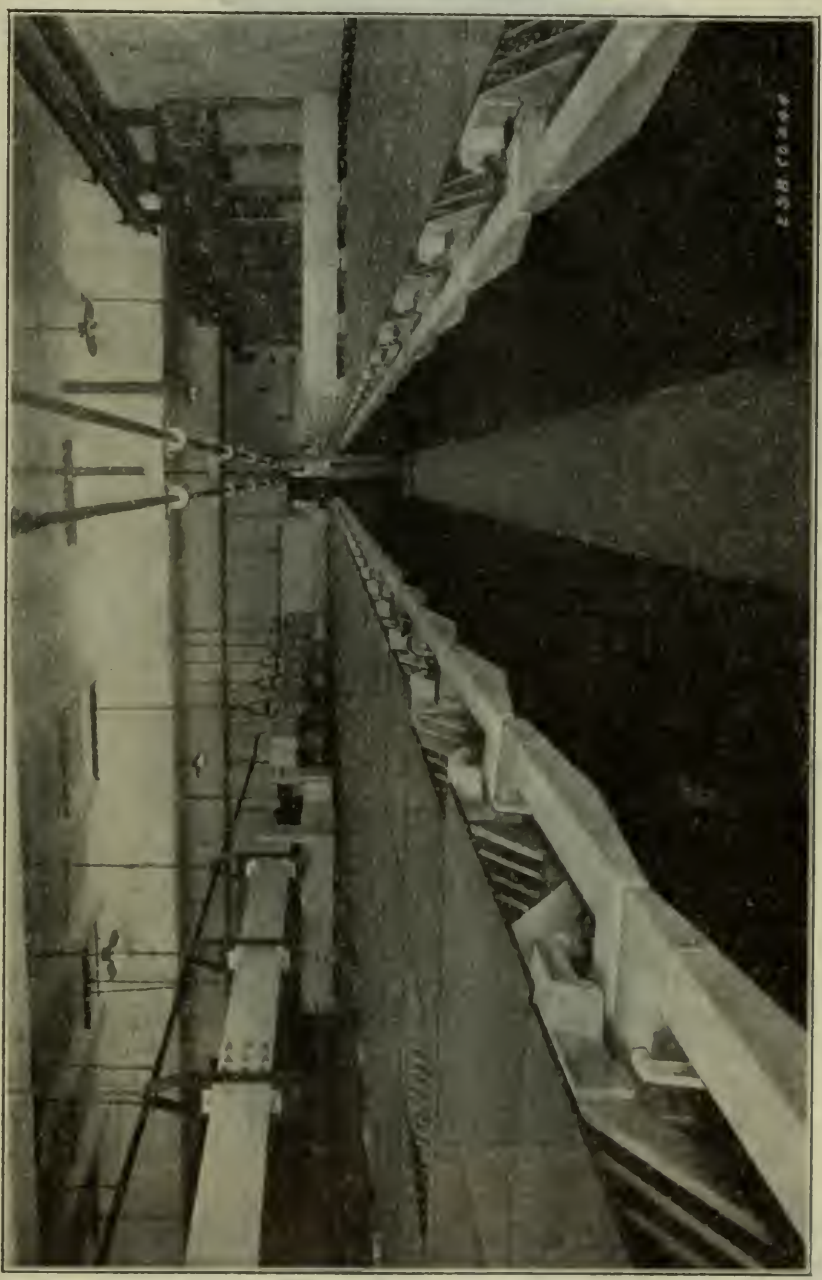


FIG. 9. "EXIDE" BATTERY AT SIXTEENTH STREET SUBSTATION, NEW YORK EDISON COMPANY.

In stationary batteries, cells in glass jars are, in some cases, supported on wooden trays filled with sand to produce a uniform distribution of pressure on the bottom of the jar; these sand trays being mounted on glass insulators. In other cases, glass sand trays provided with suit-

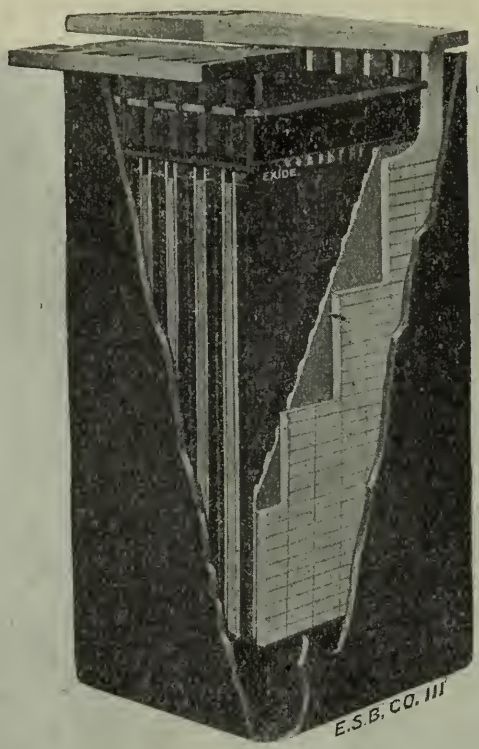


FIG. 10. RUBBER JAR CONTAINER.

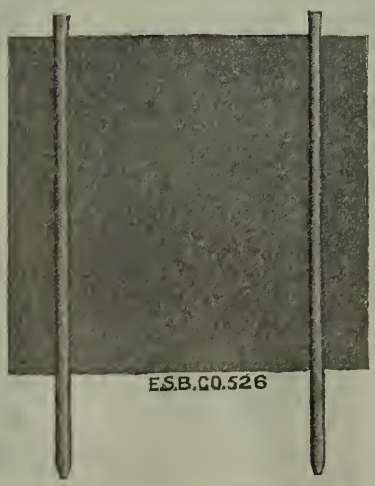


FIG. 11. TYPE "F" WOOD SEPARATOR.

able feet are used in place of the wooden sand trays with their insulators. Cells in lead-lined tanks are usually mounted on oil insulators. These consist of a glass insulator provided with an inverted petticoat, pro-

ducing a circular trough which is partly filled with oil, this insulator being covered with a lead cap extending down over the sides. In some cases, where the voltage is low and the circuit is not grounded at any point, a double tier of petticoat glass insulators may be used instead of the oil insulators. (Figs. 12 and 13.)

FIG. 12. OIL INSULATOR, UNASSEMBLED.

FIG. 13. ASSEMBLED OIL INSULATOR MOUNTED ON EARTHENWARE PEDESTAL.

The insulation of lead-lined tanks, especially in batteries connected to high voltage systems (greater than 150 volts) or in systems where one side of the circuit is grounded, is of very great importance. A slight leakage of current which may take place over the surface of insulators coated with dirt or acid-laden moisture is liable to produce electrolytic corrosion of the tank linings. The oil insulator described above has been found to practically eliminate these difficulties.

METHOD OF CONTROL AND CONTROLLING APPARATUS.

Several methods have been adopted for controlling the charge and discharge of stationary batteries. One of the most important pieces of apparatus for this purpose is the booster. This is a dynamo (which may be driven by belt or a motor) connected in series with the battery, and used to compensate for the difference in voltage between the electric circuit and the battery during charge or during discharge, or both. This booster may be controlled by manual operation of its field rheostat, or by automatic apparatus. Wherever automatic control is employed the booster usually controls both the charge and the discharge of the battery. Where control is effected by hand, the booster is generally used only for charging, and the discharge voltage is controlled by end cells, or counter electro-motive-force cells. End cells are a series of cells at one end of the battery connected to a multiple point end cell switch by which the number of cells included in the circuit may be controlled. Counter electro-motive-force cells are electrolytic cells, in which the plates are plain lead grids or dummies having no active material, and no appreciable capacity. They are connected to a multiple point switch, and are operated in the same way as a rheostat to reduce the voltage during charge, or at the beginning of discharge when the battery voltage is above that of the circuit. In some cases an ordinary rheostat is used for this purpose, but the counter cells have the advantage of cutting down the voltage by a fixed amount per cell (2.3 to 2.5 volts); this amount being but little affected by changes in the amount of current, whereas the voltage absorbed by a rheostat varies directly with the amount of current transmitted. (Fig. 14.)

Where a booster is not employed, the high voltage necessary for charging is sometimes obtained by raising the voltage of the generator. (Fig. 15.) This may be done when no current is required for lights, or if lights are burning, the lower voltage necessary may be obtained by introducing counter cells, or by an end cell switch. In other cases small stationary batteries are charged by dividing the series of cells into two equal groups which are connected across the circuit in parallel through suitable resistance, so that the voltage of the circuit need not be altered. In many small battery installations no voltage control during discharge is required. (Figs. 16, 17 and 18.)

DEFINITIONS OF COMPONENT PARTS.

Positive Plate.—Brown in color, active material lead peroxide. Figs. 3 and 5.)

Negative Plate.—Gray in color, active material spongy metallic lead. (Figs. 6 and 7.)

Positive Group.—The set of positive plates of a single cell lead burned to a connecting strap. (Fig. 19.)

Negative Group.—The set of negative plates for a single cell lead burned to a connecting strap. (Fig. 20.)

Wood Separator.—A thin wood sheet, specially treated, placed between adjacent plates in a cell. (Fig. 11.)

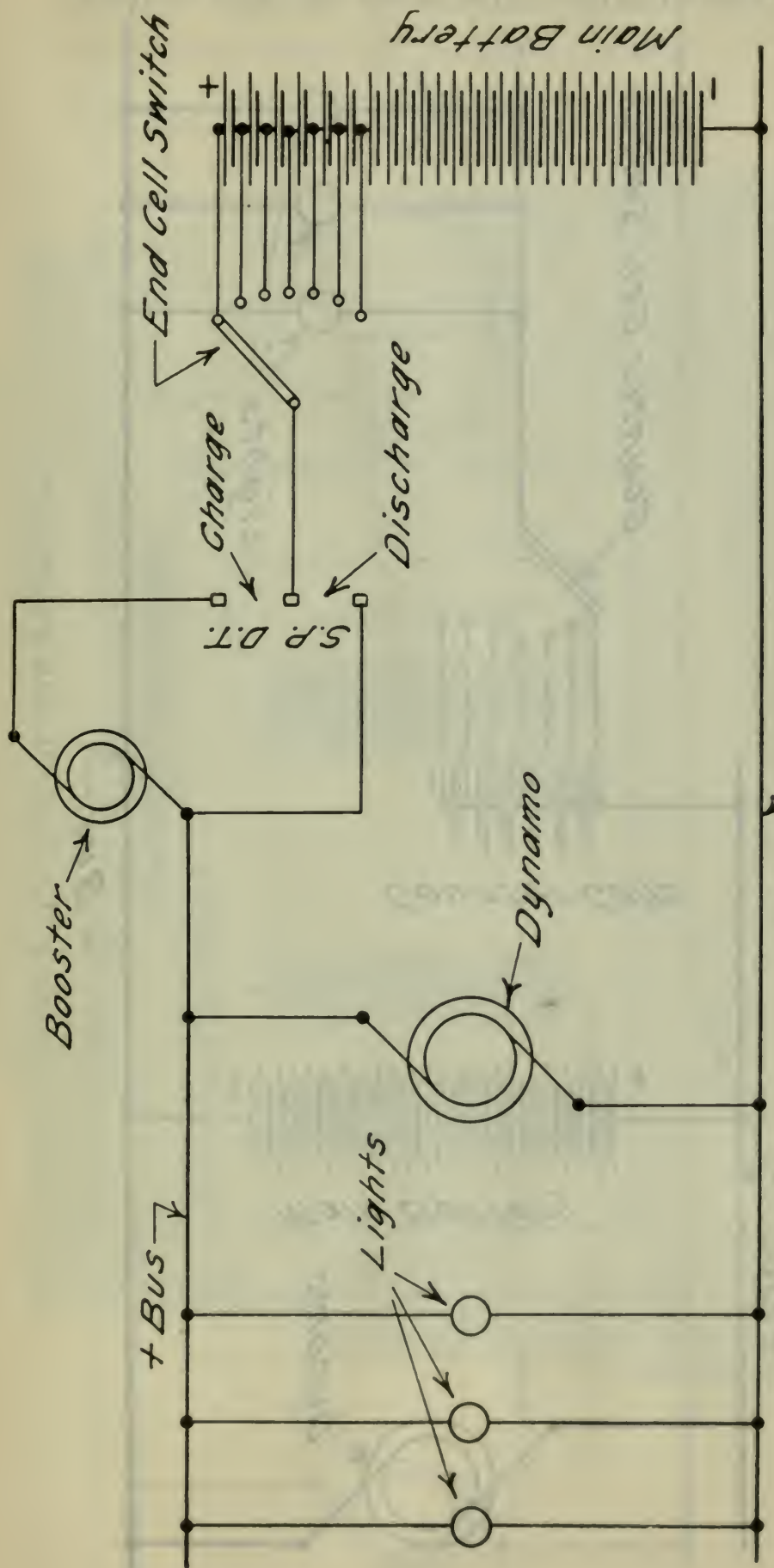


FIG. 14. BOOSTER AND END CELL. DIAGRAM OF CONNECTION.

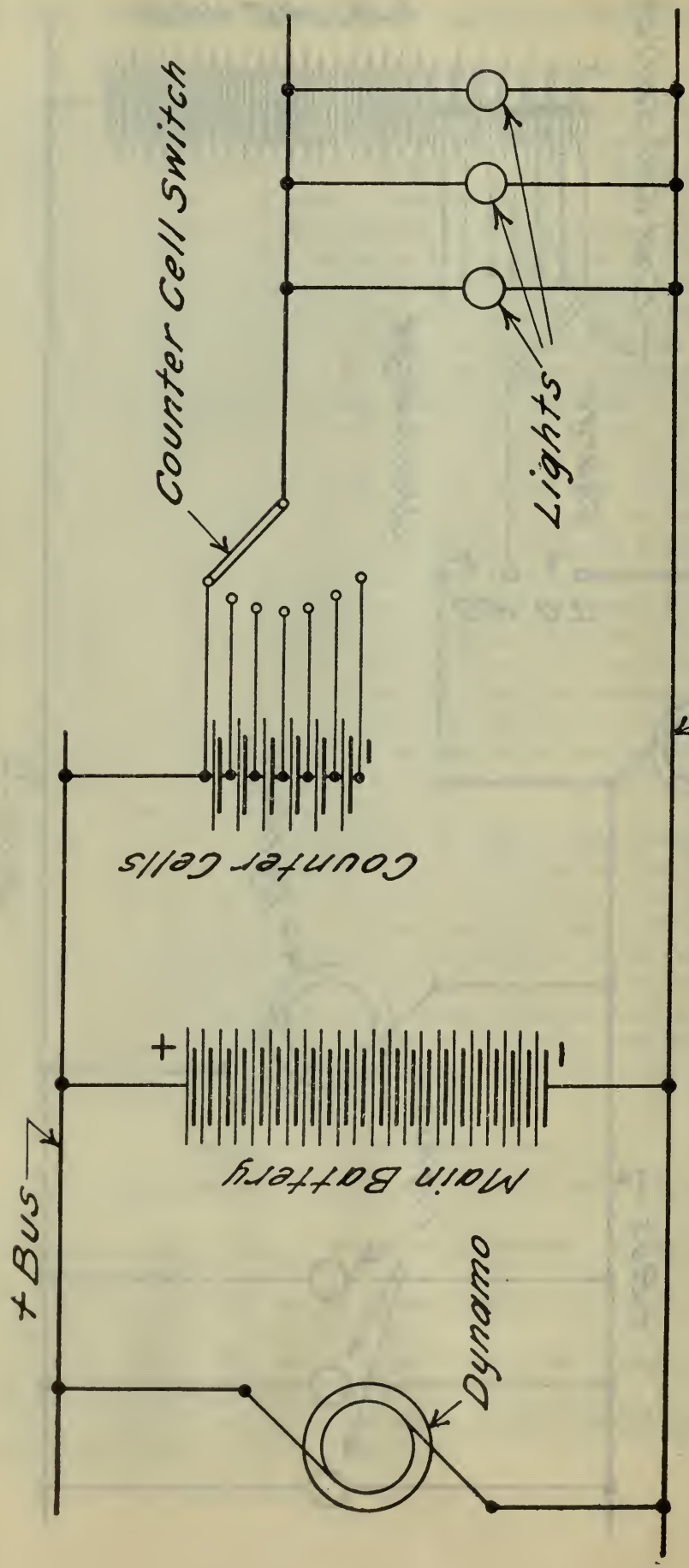


FIG. 15. COUNTER E. M. F. CELLS. DIAGRAM OF CONNECTIONS.

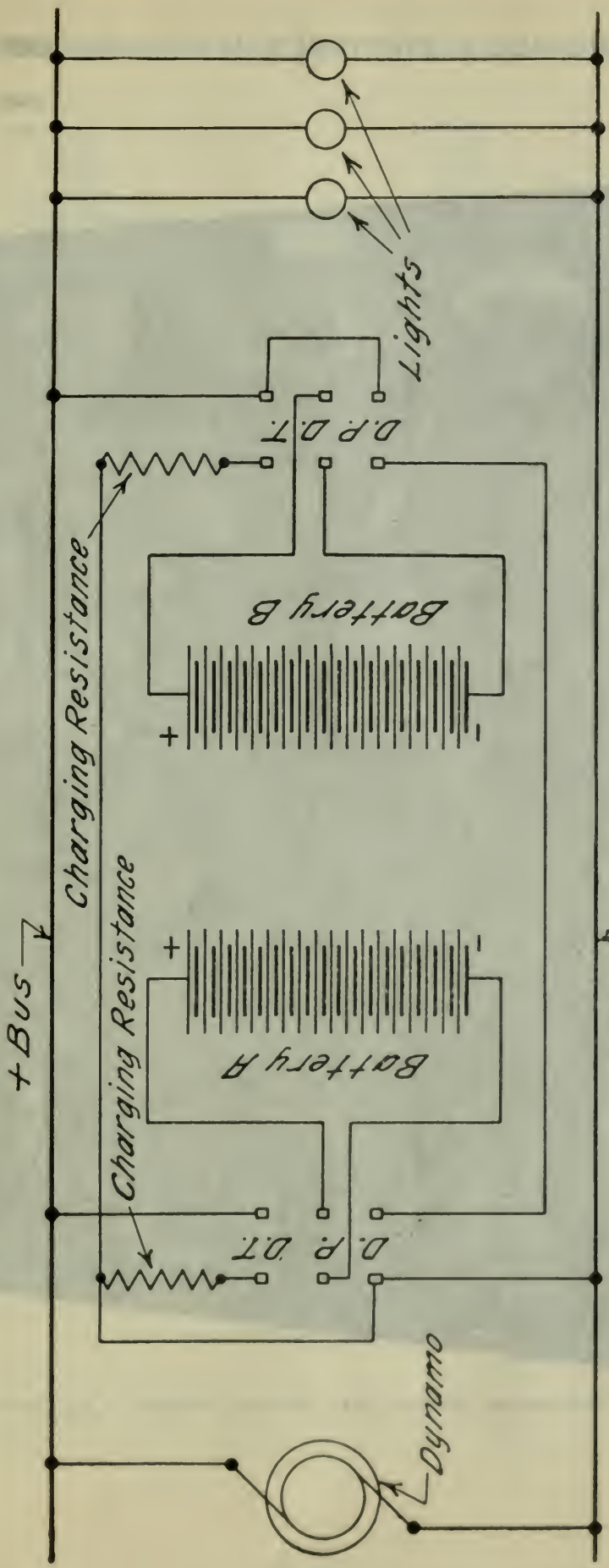


FIG. 16. PARALLEL CHARGING DIAGRAM OF CONNECTIONS.

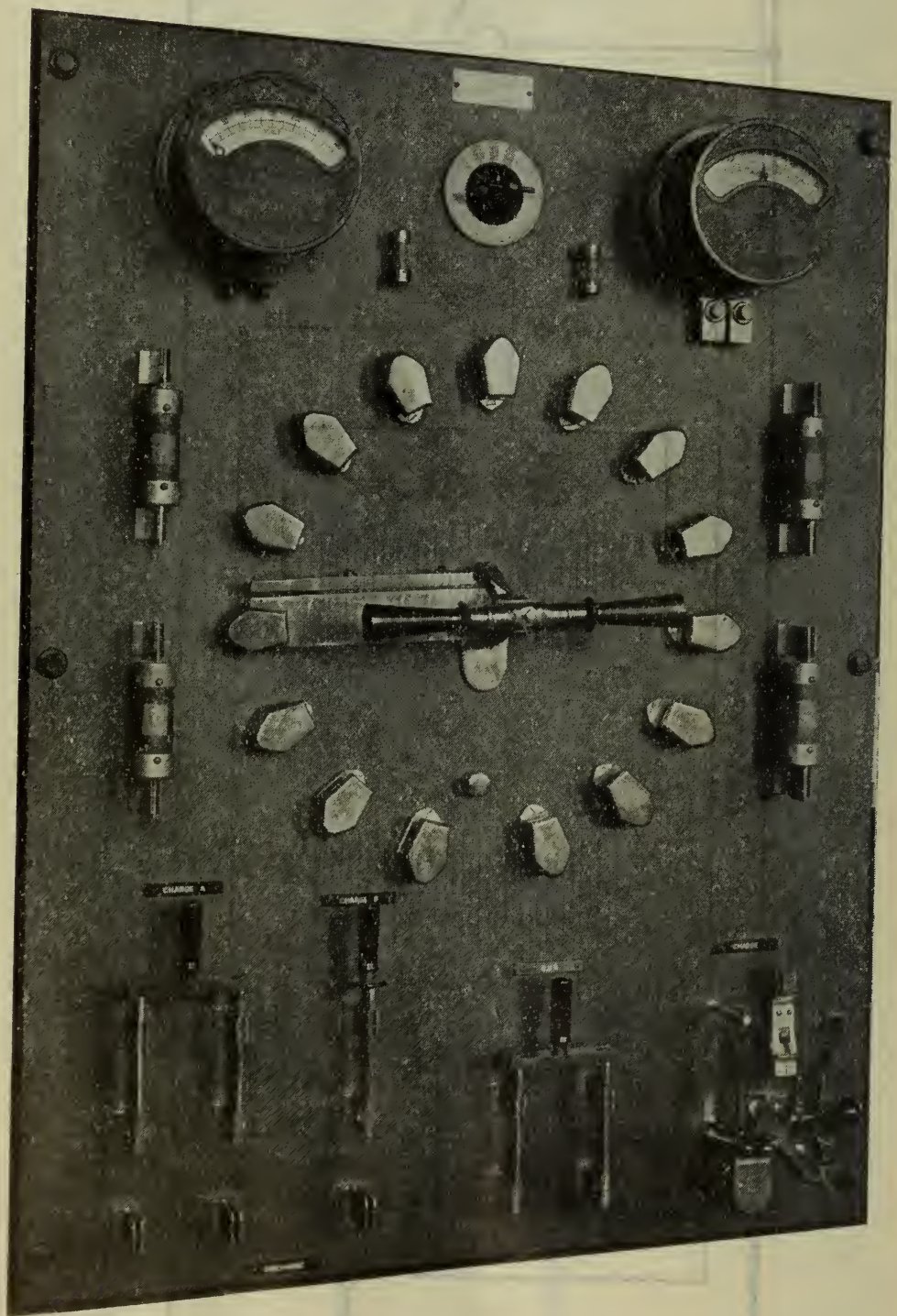


FIG. 17. SWITCHBOARD FRONT WITH ROUND PATTERN CELL SWITCH.

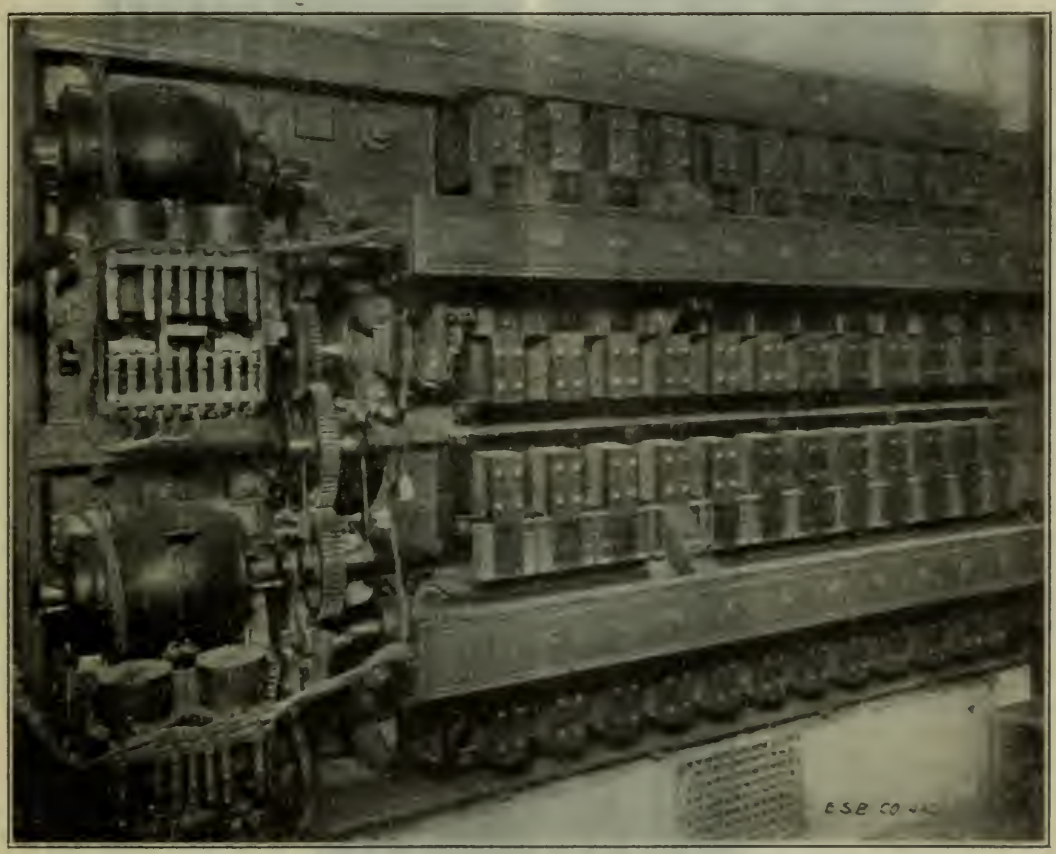


FIG. 18. REMOTE CONTROL CELL SWITCH. TWO OF THE FOUR END CELL SWITCHES INSTALLED IN THE SIXTEENTH STREET SUBSTATION OF THE NEW YORK EDISON COMPANY. MAXIMUM CAPACITY, 20,000 AMPERES EACH.

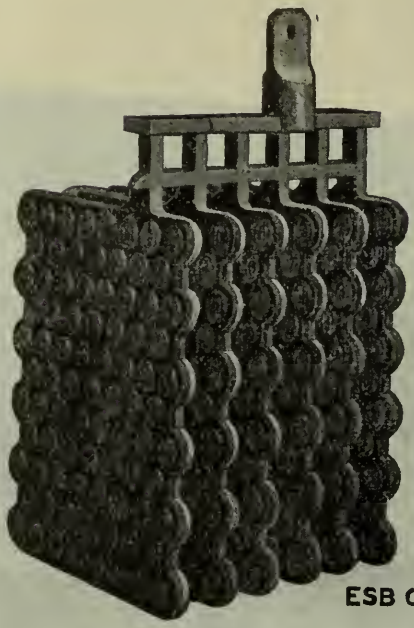


FIG. 19. MANCHESTER POSITIVE GROUP.

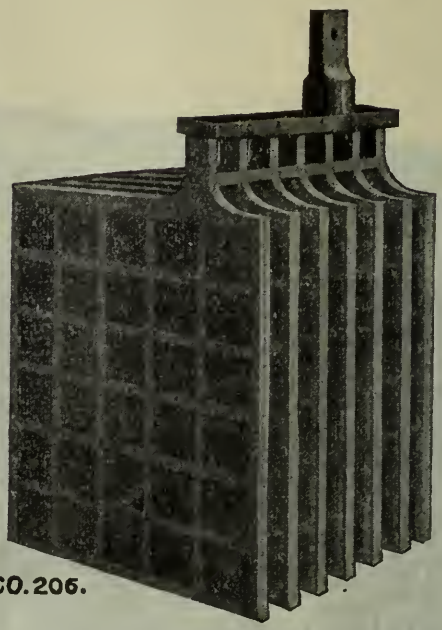


FIG. 20. BOX NEGATIVE GROUP.

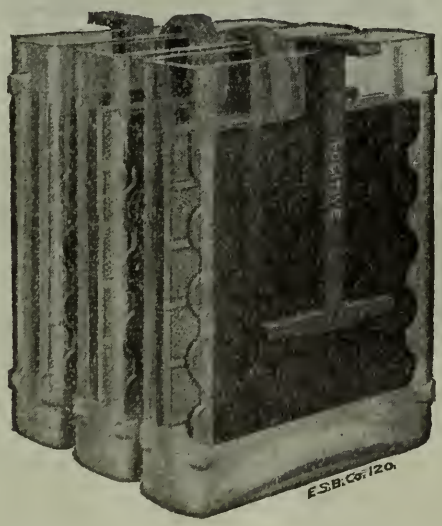


FIG. 21. TWO PLATE TYPE. "ET" ELEMENTS IN GLASS JARS.

Rubber Separator.—A thin sheet of perforated hard rubber used between adjacent plates, either alone or with a wood separator. (Rubber separators are not used in stationary batteries.)

Hold-down.—A glass weight used in stationary batteries to prevent wood separators from floating.

Element.—A positive group and a negative group with separators and hold-downs assembled for a single cell. (Fig. 21.)

Electrolyte.—The fluid or solution in the cells consisting of dilute sulphuric acid.

Cell.—A single jar or container equipped with element and electrolyte. (Fig. 21.)

Two-Plate or Couple-Type Cell.—A cell containing only one positive and one negative plate. In a series of such cells the positive plate in one is permanently connected to the negative plate in the next by a "U"-shaped lead strap which supports the two plates on the edges of the jars. (Fig. 21.)

Multiple Plate Cell.—A cell having more than two plates. In such a cell there is always one more negative plate than positive, the outside plates being always negatives.

Pilot Cell.—One cell of a series selected for taking readings of voltage and specific gravity to indicate the condition of the entire series.

SPECIAL INSTRUCTIONS REGARDING LEAD STORAGE BATTERIES.

Complete instructions for the care and operation of lead storage batteries are issued by the Manufacturing Companies. A few of the most important points, however, are given below:

Keep the level of the electrolyte above the plates. For this purpose add only pure water; never add electrolyte or acid, except to replace loss by spilling. Weakness of the acid in the cells is an indication of a discharged condition of the plates and the acid density should be restored by charging, and not by the addition of acid. Such low specific gravity in a single cell of a series may be the result of a short-circuit between the plates. After removing this short circuit the cell may be separately charged or the entire series may have to be overcharged in order to bring this cell up to equality with the rest.

Do not over-discharge a battery. High rates of discharge in amperes are not injurious, but excessive discharge in ampere hours will shorten the life of the plates.

Do not overcharge. Charging should preferably be done at the normal or eight-hour rate of the cells, and should not be continued after the cells are fully charged. Higher rates than the normal are permissible at the beginning of the charge, but the rate should be reduced to normal toward the end when gassing begins.

Do not allow cells to stand for a considerable length of time in the discharged condition. After a battery is discharged it should be recharged within a few hours. This is particularly important if the full capacity of the battery has been taken out.

Do not allow any foreign material whatever to get into the cells.

Ventilate the battery compartment. This is especially necessary when charging, as the gases given off form a mixture when confined, which may explode in the presence of an exposed flame.

Never allow the sediment which accumulates in the bottom of the jars to reach the plates.

THE EDISON STORAGE BATTERY.

There are many combinations which can be utilized as secondary storage batteries, wherein when charged with a current of electricity, by virtue of the electro-chemical action, a portion of the electric current is returned in the reverse direction of the charge. Of the various combinations, however, none excepting the lead sulphuric acid battery has proven commercially practicable, until within the past few years, when through the genius of Thomas A. Edison a combination has been successfully developed which has for one of its electrodes nickel oxide and for the other finely divided iron or iron sponge, these being immersed in a solution of potassium hydrate.

THEORY OF CHEMICAL REACTION.

Starting with oxide of iron in the negative electrode, green nickel hydrate in the positive electrode and potassium hydrate in the electrolyte, the first charging of a cell reduces the iron oxide to metallic iron while converting the nickel hydrate to a very high nickel oxide, black in color.

On discharge, the metallic iron is converted back to iron oxide and the high nickel oxide to a lower oxide, but not to its original form of green hydrate.

In every cycle thereafter the negative active material charges to metallic iron and discharges to iron oxide, while the positive active material charges to a high nickel oxide and discharges to a lower oxide.

Current passing in the direction of charge or discharge decomposes the potassium hydrate of the electrolyte, and the oxidation and reductions at the electrodes are brought about by the action of its elements. An amount of potassium hydrate equal to that decomposed is always reformed at one of the electrodes by a secondary chemical reaction, and as a result none of it is lost and its density remains constant.

The result of charging, therefore, is the transference of oxygen from the negative to the positive electrode and a discharging of a transference back again of oxygen from the positive to the negative electrode.

A comparison of the two types of batteries may be made as follows:

	Element.	*Lead Battery.*	*Edison Battery.*
(1)	Positive Plate,	Lead Peroxide	Nickel Hydrate
(2)	Negative Plate,	Sponge Lead	Iron Oxide
(3)	Electrolyte,	Dilute Sulphuric Acid	Potassium Hydrate
(4)	Insulation,	Wood, Rubber or Porcelain	Hard Rubber
(5)	Container,	Glass, Rubber or Lead Lined Tank	Nickeled Steel Cans
(6)	Trays,	Wood	Wood with Steel Cradles
(7)	Connectors,	Lead Straps Burned on	Copper Wire Steel Lugs

A description of the component parts of the Edison Batteries follows:

POSITIVE PLATE.

The positive plate consists of one or more perforated steel tubes, nickel plated, filled with alternate layers of nickel hydroxide, and pure metallic in thin flakes which form the active material.

The tube is drawn from a perforated steel ribbon, and has a spiral lapped seam. After being filled with the active material, the tube is reinforced with eight steel bands equally spaced to prevent expansion and breaking of contact of tube with its contents. (Fig. 22.)

NEGATIVE PLATE.

The negative plate consists of a grid of cold-rolled steel, nickel plated, holding a number of rectangular pockets of perforated steel, also nickel plated, which contains powdered iron oxide, the active material. After the pockets are filled they are inserted in the grid and compressed

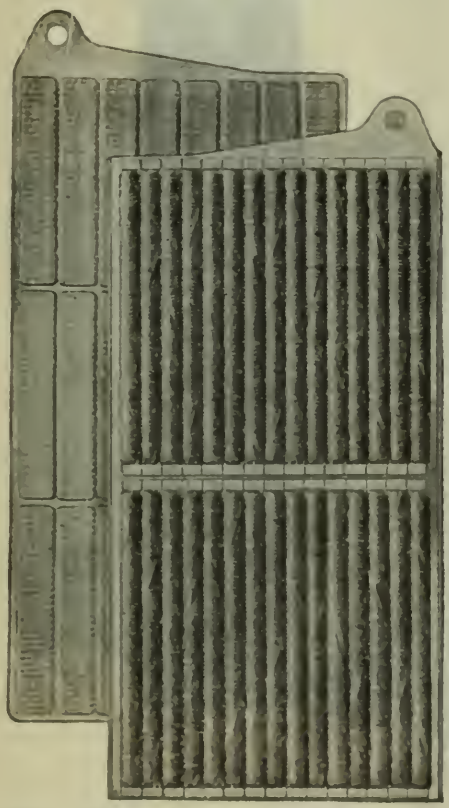


FIG. 22. POSITIVE AND NEGATIVE PLATE.

FIG. 23. INSULATION.

between dies, corrugating the surface of the pockets, and forcing them into integral contact with the grid. (Fig. 22.)

ELECTROLYTE.

The electrolyte consists of a 21 per cent. solution of potash in distilled water, added to which is a small per cent. lithia.

INSULATION.

After the plates are assembled narrow strips of hard rubber are inserted between the plates, separating and insulating them from each other. The side insulators have grooves to fit the edge of the plates, separating the plates from the steel container. At the ends the negative plates are separated and insulated from the steel container by means of smooth hard rubber sheets. At the bottom the plates rest upon a hard rubber rack or bridge, insulating the plates from the bottom. Very little space is required at the bottom, as no active material is precipitated. (Fig. 23.)

CONTAINER OR JAR.

The container or jar is made of rolled sheet steel, nickel plated, with welded seams. The sides of the jar are corrugated to increase the strength. (Figs. 24 and 25.)

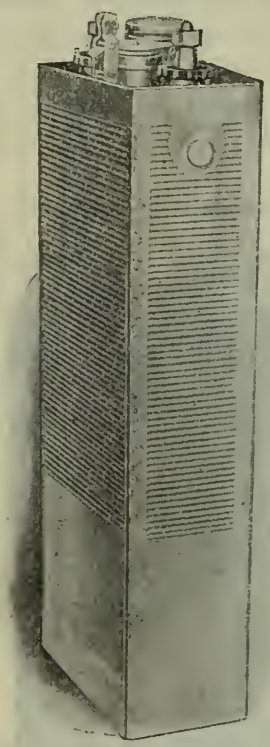


FIG. 24. CONTAINER OR JAR.

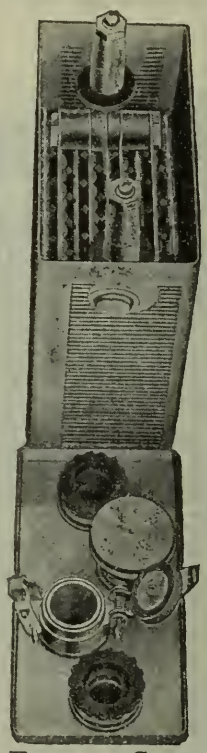


FIG. 25. CELL.

TRAYS OR BOXES.

The assembled cells are enclosed in wooden trays of special construction, using light wood. The cells rest directly upon a steel cradle, which is supported on the lower side slats of the tray. The cells are held in place by steel hold-downs, attached to the upper side slats. The trays have no bottoms, the cells being supported by the cradles. (Fig. 26.)

CONNECTORS.

The plates of a cell are assembled on steel connector rods, with steel spacing washers, all attached to a steel terminal post, the outer

end of which is tapered to fit a terminal lug. The tip of the terminal is threaded to receive a nut to hold down the lugs. The terminal post is insulated from the cover of cell by means of hard rubber washers and bushings. (Fig. 27.)

The terminal lug is of drop forged steel made to fit the terminal post. The connecting link between two terminal lugs is copper, swedged into the lugs.

VOLTAGE.

To charge an Edison Battery to full capacity a D. C. voltage of 1.85 volts per cell should be provided. A 60-cell battery requires, therefore, a D. C. voltage of 60x1.85, or 111 volts.

The normal discharge rate of the Edison Battery is 1.2 volts per

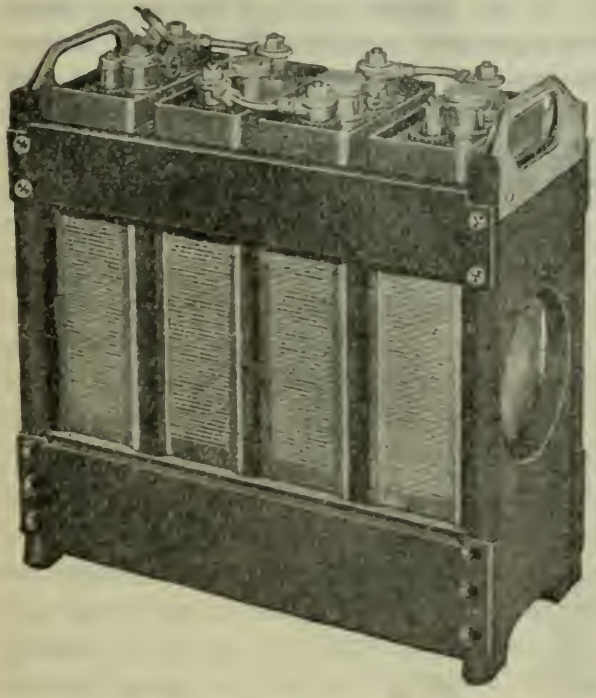


FIG. 26. TRAYS OR BOXES.

FIG. 27. CONNECTORS.

cell. The terminal voltage divided by the average voltage per cell will give the required number of cells.

EFFICIENCY.

The efficiency of any battery is the ratio of the discharge to the charge, of the electric energy derived from the discharge, or use of the battery, divided by the electric energy expended in charging the battery.

The watt hour efficiency of the Edison battery, at the normal discharge rate, is approximately 58 per cent. The watt hour efficiency of the lead storage battery at the normal discharge rate is approximately 75 per cent.

While this is the efficiency of the two types of batteries, as far as the relation between input and output of energy is concerned, it does not take into account other considerations which affect the life and maintenance of the various types of batteries.

Some of the advantages claimed for the Edison type of battery are as follows:

Longer life due to the use of nickel steel in the elements and an alkaline solution as an electrolyte eliminating corrosion of parts.

Lighter weight per unit of energy output due to the use of lighter material in plates and parts of battery. No injury is done to cells if battery is overdischarged and if left discharged.

Absence of such difficulties as sulphation, buckling of plates, loss of active materials, sedimentation, breaking of jars from vibration, corrosion of plates and grids.

The first cost, however, of the Edison type of battery is about twice that of a lead battery of equivalent capacity. The Edison Battery has not been in general commercial use long enough, in competition with the lead battery and under equal conditions of service, to demonstrate whether its life is twice that of the lead battery and whether or not, therefore, it is more economical as far as first cost is concerned.

APPLICATIONS IN RAILWAY SERVICE.

The applications of the storage battery in railway service may be enumerated as follows:

Train Lighting.
Signaling.
Draw-bridge Operation.
Lighting of Stations and Terminals.
Storage Battery Traction.

TRAIN LIGHTING.

The principal systems of train lighting are: Straight storage, axle lighting and the head-end system.

In the straight-storage system the batteries are used to carry the entire lighting load during the trip, and sometimes during a complete round trip, the charging being done at the terminals. Where the run is not so long as to require excessive battery capacity or to endanger over-discharge, and where the service is sufficiently regular to insure that the batteries receive proper care and systematic inspection, the straight-storage system is eminently satisfactory.

The head-end system has been adopted where the run is too long to permit straight storage, but the train makes the entire run as a unit, and is not sub-divided for service on branch lines. In this system a battery may be installed on each car, or several batteries may be distributed throughout the train and a dynamo is installed either on the engine or baggage car at the head of the train, driven by steam from the locomotive boiler. The dynamo is run at a voltage sufficiently high to take the lighting load when the steam supply is available, the batteries floating across the circuit under these conditions without any considerable amount of charge or discharge. When the engine is disconnected, the batteries supply current for the lights. Under normal conditions of service the amount of discharge taken from the batteries is comparatively small, and it may be restored by raising the voltage of the dynamo during a daylight run when the lamps are disconnected, or the batteries may be recharged at the terminals.

Whenever the conditions are not suitable for straight storage, or the head-end system, as, for example, where cars are liable to be operated on branch lines, without facilities for recharging, or where the service is intermittent and irregular, the axle lighting system is very generally

adopted. In this system a dynamo is mounted on one of the trucks, and driven by belt or chain from one of the axles. In order to control the voltage of the dynamo to compensate for the variable speed at which it is driven, many automatic regulating devices have been introduced. In general these devices are designed to maintain a constant current output from the dynamo, regardless of speed, and are controlled by this current output in such a manner that variations within certain limits will vary the field excitation of the dynamo to produce the desired regulation. The output of the dynamo being maintained practically constant, it is obvious that when there is no lamp load, the entire output will be utilized for charging the battery. As the lamps are turned on the amount of current delivered to the battery is reduced, and if the demand under maximum load conditions is greater than the output of the dynamo, the battery will discharge to assist the dynamo in carrying the load. When the car speed is below a certain limit, the voltage of the dynamo cannot be maintained, and an automatic switch disconnects the dynamo, leaving the battery to carry the entire load. This switch again closes automatically when the voltage of the dynamo has reached a proper value.

The varying charging current into the battery, and the varying state of its charge, produces a considerable variation of voltage at the battery terminals. In order to prevent this variation from affecting the brilliancy and life of the lamps, a lamp regulator is ordinarily introduced to control the lamp voltage by varying a resistance in series with the lamp circuit. In the earlier axle lighting systems the constant output of the generator was adjusted to keep the battery fully charged under maximum load conditions, and whenever the load conditions were less severe the excess output produced serious overcharging of the batteries, and a marked reduction in their normal life. Recently, automatic devices have been introduced to reduce the output of the generator, and avoid some of this overcharge when the battery voltage rises to a certain point. This does not entirely eliminate overcharging, but reduces it appreciably.

One modification of the head-end system has been tried with some success, under special conditions, in which a battery is located at each end of the train instead of on each car, with a dynamo at the locomotive end. This system provides for keeping the lights burning when the train is parted in the middle, but does not, of course, provide for cutting out an individual car.

Train lighting batteries are mounted in compartments supported under the car-bodies, and generally consist of separate units, each containing two cells mounted in a wooden crate. (Fig. 29.) In most cases two-compartment lead-lined wooden tanks are adopted, the plates being supported by porcelain wedges on the bottom of the tank. In some cases hard rubber jars are used, embedded in insulating compound, which fills the entire space between the jars and the wooden crate, the jars

FIG. 29. TWO-CELL UNIT OF TYPE 13 "EP," IN LEAD LINED TANK WITH SPECIAL CONNECTORS.

FIG. 30. TWO-CELL UNIT OF TYPE 11 "EP" IN RUBBER JARS, WOOD CRATE.

being floated in while the compound is hot. (Fig. 30.) Hard rubber covers are used which fit the jars and the terminals, and are sealed in with compounds, so as to prevent the slopping of acid, a vent being provided to allow the escape of gases while charging.

Two different voltages are being extensively used in train lighting, namely, 64 and 32 volts, calling for 32 and 16 cells respectively. Owing to the introduction of the Tungsten lamp, and its greater ruggedness at

lower voltages, the 32-volt systems are becoming more generally standardized, especially for axle lighting systems. The higher voltage is still used for head-end systems on account of the drop in train line conductors, and for straight storage on account of the additional capacity obtained by the increased number of cells, which would involve excessive size and weight of individual cells at the lower voltage.

SIGNALING.

In signal service the storage battery has, in many situations, supplanted the primary battery. It is generally found less expensive to maintain, and it also offers other advantages over the primary cell, such as low internal resistance, uniform voltage and large output for intermittent service, such as the operation of motor-driven signals. In some cases portable batteries are employed for this purpose, which are collected at regular intervals for charging at some convenient charging point, a certain number of spare batteries being provided for service while the discharged cells are being charged. (Fig. 31.) In other sys-

FIG. 31. FOUR SS 9 SIGNAL CELLS ASSEMBLED IN CASE.

tems the batteries are charged without removal by a charging circuit which extends along the right-of-way, into which the cells may be connected in series. Duplicate batteries are installed, one of which is connected to the charging circuit, while the other is supplying the current to the signals. In some cases the storage cells are connected in parallel with a sufficient number of primary cells of the "gravity" or "bluestone" type. These primary cells supply a small amount of current continuously, sufficient to keep the storage cells fully charged, while the storage cells,

on account of their low internal resistance, furnish the high momentary current demands for operating the signals. The choice between primary batteries and storage batteries for signal service, as well as the best method of charging the cells, will depend upon local conditions, particularly on the space between the signals and the facilities available for charging.

DRAWBRIDGE OPERATION.

The introduction of storage batteries for supplying current for operating motor-driven drawbridges has been quite general of recent years. The battery in this service has two important functions. The first is to provide an absolutely reliable source of current which is not subject to interruption. Accidents which have occurred, due to failure of power while a large vessel, under considerable headway, is approaching a partially opened drawbridge, have shown the necessity for such an auxiliary supply of current. The second function is to provide, by means of a small continuous current supply, for the heavy intermittent service required. The 24-hour average demand of the drawbridge is usually very small as compared with the momentary maximum demand. By the installation of a storage battery, the primary source of current, which may be a dynamo driven by a gasoline engine, or a motor generator set operated by alternating current supplied from a distance, may be only sufficient for the average requirements, and for charging the battery at its normal rate. On discharge, the battery may be called upon for an output up to eight times its normal rate, or under certain conditions for even greater discharge rates, for furnishing the heavy momentary currents required for operating the bridge. This function of the battery, by reducing the maximum demand on the primary source of power, not only reduces the amount of investment for generating machinery, but where power is purchased it will often make a marked reduction in the power bills. Another advantage of the battery in this service is to permit a 24-hour supply of current with only a few hours' operation of the generating machinery; the battery having no moving parts does not require constant attendance, and the cost of labor may thus be reduced. (Figs. 32 and 33.)

STATION LIGHTING.

For the lighting of stations and terminals the storage battery is a valuable adjunct to the power plant, permitting the latter to be shut down entirely during the hours of lighter load when the battery supplies the entire demand, and also assisting the generating machinery during the few hours of excessive or peak load. Such a battery is usually charged from the station bus by means of a booster, which is a motor-driven dynamo connected in series between the bus and the battery, and supplies the additional voltage required for charging. The discharge of such a battery is controlled by end cells connected to a multiple point end cell switch which may be operated by hand, or by remote control apparatus to cut cells into or out of circuit, for controlling the battery voltage, and the amount of discharge current when the battery is operating in parallel with the main generator.

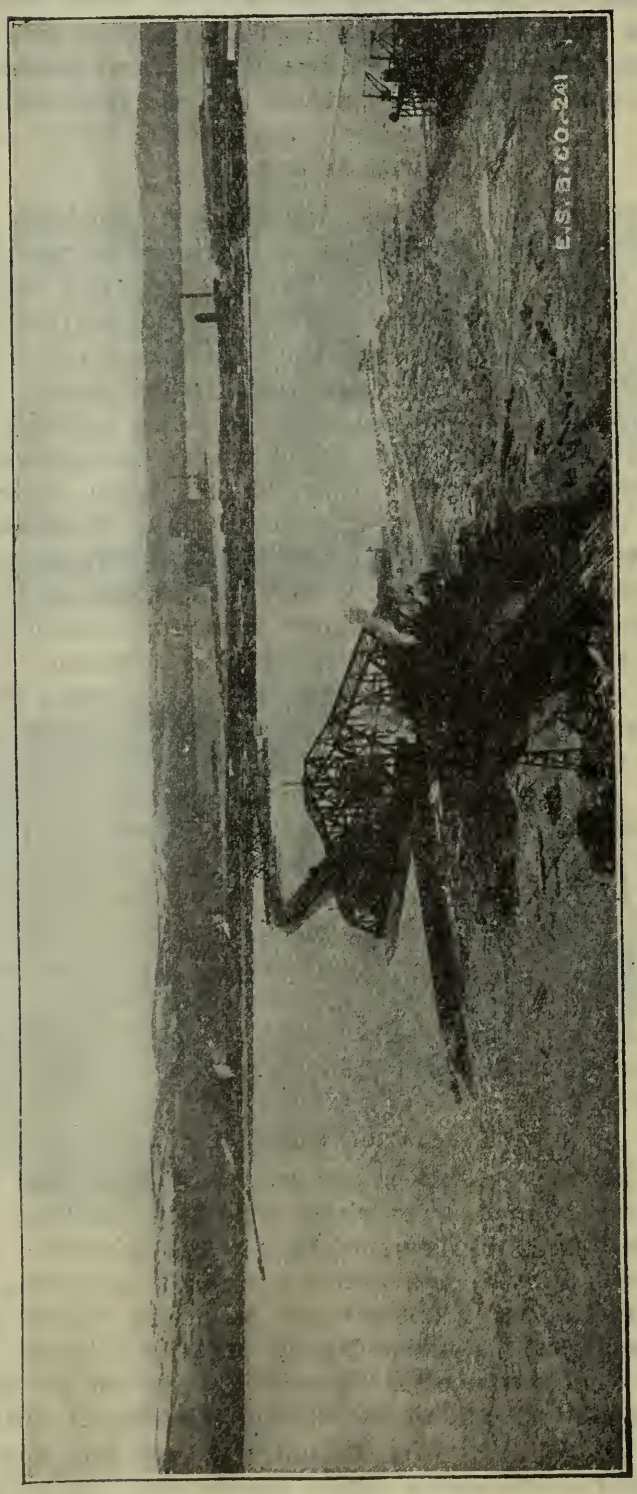


FIG. 32. NORTHERN PACIFIC RAILWAY BRIDGES AT DULUTH, MINN., AND SUPERIOR, WIS., EQUIPPED WITH "CHLORIDE ACCUMULATORS."

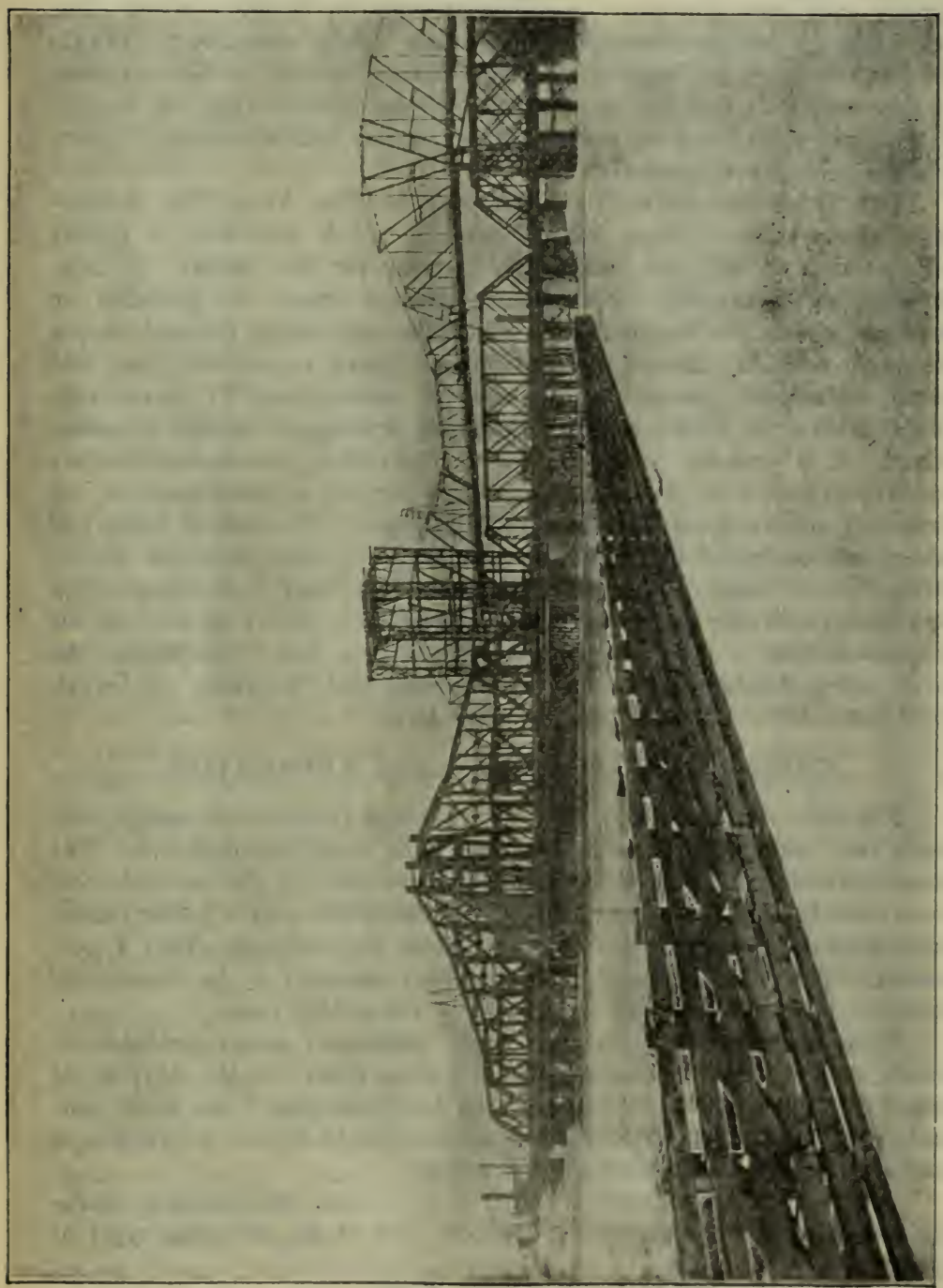


FIG. 33. CHICAGO & NORTHWESTERN RAILWAY DRAW SPAN AT CLINTON, IOWA, OPERATED BY "CHLORIDE ACCUMULATORS."

STORAGE BATTERY TRACTION.

In the early history of storage battery development considerable attention was paid to storage battery traction, and a number of storage battery cars were put into commercial service on different roads. For one cause or another, however, these were finally abandoned. Within the last two years this application of the storage battery has been revived, largely owing to improvements in the storage battery itself, as well as to a better knowledge of the conditions under which storage battery traction will prove successful.

The Third Avenue Railroad Company, in New York City, is operating about eighty storage battery cars, in which lead storage battery cells carried on the cars furnish the current for the motors; 58 cells, each having a capacity of about 400 ampere hours, are installed on each car under the longitudinal seats, these cells being charged during the night without removal from the cars. Some experiments are also being made with storage battery cars on branch lines of steam railroads, where the traffic is light, and only infrequent service is maintained. It is probable that in many such situations the storage battery car will prove to be the most economical method of providing for the passenger service from a commercial standpoint. The cost of labor and power will be less than for locomotive operation, and the initial investment will, in many cases, be considerably less than that required for equipment with the overhead trolley, particularly where power can be purchased from a local lighting company, at a low rate, during the hours when the lighting load is a minimum, and, therefore, no investment for additional machinery is called for.

STORAGE BATTERY CHARGING APPARATUS.

The means employed to supply a charging current for storage batteries vary with the circumstances surrounding each individual case. The most desirable condition is that in which current can be secured from some outside source, available without the installation of a prime mover. Such conditions are provided in cases where there already exists a generating plant, either operated by the railway company or by commercial concerns where current can be secured at reasonable rates.

There may, however, be no outside sources of power available, in which case it becomes necessary to install a plant for the purpose of generating the charging current; or the condition may arise where current is available, but it is of such a character as to require conversion as may be necessary, for charging the batteries.

The character of equipment required to provide the necessary charging current will usually consist of one or more of the following types of apparatus:

(1) Motor Generator Sets.
(2) Mercury Arc Rectifier.
(3) Rotary Converters.
(4) Steam Turbine Unit.
(5) Steam Engine Unit.
(6) Internal Combustion Engine Unit.

The first three types named are simply converters of electrical energy, and presuppose that current of some character is available from an outside source, which only requires a change in its character to conform to the required charging current.

Types (4) and (5) are usually used where steam supplies are available, but where separate steam supply is necessary for the installation of this type of generator it may become prohibitive.

Type (6), the internal combustion engine with its various available types using low grade of oil products for fuel, is the most practical and economical type of installation, where no external source of power or energy is available.

The various types are more fully described as follows:

(1) *Motor Generator Sets.*—Motor Generator sets are in common use for battery charging installations. They should be preferably direct connected. They are adaptable to the various voltage and current requirements. While constant voltage is desirable for driving the motor, even such fluctuating current as trolley current may be used, with proper automatic voltage regulator.

Motor Generator sets are either of the D.C.-D.C. or A.C.-D.C. type, the former known as the direct current generator set. The generator should be shunt wound with considerable range of voltage, through regulation of field by suitable rheostats. Moderate speeds are recommended for mechanical reasons. The generators are shunt wound for 125 volts with variation of from 70 to 140 volts. Motors are furnished for 115, 230 or 550 volts D.C. Capacities range from 125 watts to 12.5 k.w.

In many localities it is possible to secure at fair rates supplies of alternating current, usually at 60 cycles, single or three phase at suitable voltages. The A.C.-D.C. motor generator sets are frequently used in such cases to convert the current for charging purposes. The generators are shunt wound for 125 volts normal operation and range from 70 to 140 volts. Motors may be 110, 220, 440 or 550 volts for two or three phase current. Capacities range from 200 watts to 10 k.w.

(2) *Mercury Arc Rectifiers.*—Mercury Arc Rectifiers, with the improvements made in recent years, are proving one of the most practicable and economical devices used in battery charging. They are complete in themselves, requiring no auxiliary apparatus not available in small floor space. They are furnished in standard sizes from 0 to 175 volts D.C., and in capacity from 10 to 50 amperes. Where battery charging is done at a terminal for car lighting service it is possible to use a number of rectifier panels side by side to obtain the necessary amount of current required.

Ordinarily Rectifiers are designed for operation where the Alternating Current furnished has a frequency of 60 cycles and at from 110 to 220 volts, single phase. They are, however, readily adapted to other voltages and frequencies down to 25 cycles. Rectifiers are simple in design and very satisfactory in operation within the limits to which they are adapted.

(3) *Rotary Converters.*—The Rotary Converter in small sizes for use in battery charging is not in great demand on account of its cost and characteristics. The impressed alternating current voltage bears a constant ratio to the direct current voltage current generated by the rotary converter, so that the direct current voltage can only be changed by regulating the alternating current voltage. The ratio of A.C.- to D.C. current is 6/10 in three-phase circuits and 7/10 in single and two-phase circuits. On account of these limits of voltage regulation the rotary converter has not been used in small capacities such as apply to battery charging.

(4) *Steam Turbine Units.*—Small Steam Turbine driven units for direct current generation have not been generally installed for battery charging purposes. Such units can, however, be secured and may prove economical where a source of steam supply is available without special steam supply installation. There are numerous types of steam turbines available, the smaller units ranging from 7 to 15 k.w., speeds 4,500 to 5,000 R.P.M., with shunt-wound generators 125 volts normal operation and a range with field regulation to give voltages ranging from 65 to 140 volts.

(5) *Steam Engine Units.*—Where a steam supply is available, a direct or belt connected steam-engine-driven generator unit is one of the most practicable outfits for battery charging. These are adapted to steam pressures as low as 80 lbs. They occupy little floor space and, when supplied with fly-wheel and closely regulating governor for speed regulation, result in practically constant voltage, eliminating automatic regulators for voltage. The direct-connected steam units range from 25 to 50 k. w.

(6) *Internal Combustion Engine Units.*—The devlopment of the internal combustion engine, especially the types using low grades of oil for fuel, opens up a wide field for the application of such prime movers. They are built with various numbers of cylinders and either two or four cycle operation. When reliably built and of good design, they provide the most economical prime movers adaptable for charging service at isolated locations. They can be secured in sizes varying from 1 to 25 k. w.

This type has the advantage of being capable of mounting on a car and thereby providing a portable charging plant which can be utilized wherever desired.

In general, the selection of types of apparatus for proposed charging plants should be made only after special investigation into the power supply conditions at each particular point.

In the limited quantities of current required for charging stations, current can ordinarily be purchased more cheaply, or as cheaply, as it can be generated independently, and where this can be done much annoyance and expense may be saved by utilizing such sources of supply.

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